QUAIN'S

ELEMENTS OF ANATOMY

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SPLANCHNOLOGY.

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ADVERTISEMENT TO THE TENTH EDITION.

The successive Editions of Dr. Jones Quain's "Elements of Anatomy" were, up to the Fourth inclusive, published under the superintendence of the original author. At his death the duty of editing the Fifth Edition, which was published in 1845, was undertaken by Mr. Richard Quain, then Professor of Anatomy, and by Dr. William Sharpey, who occupied the chair of General Anatomy and Physiology in University College. On that occasion extensive changes were made throughout the work, and a great part was rewritten. This applies especially to the General and Visceral Anatomy, edited by Sharpey, in which that distinguished Anatomist and Histologist published many valuable original observations. Indeed from this time for 35 years the influence of Sharpey was conspicuous throughout this part of the work, which was frequently referred to as "Quain and Sharpey's Anatomy."

In the Sixth Edition the place of Mr. Richard Quain was taken by Mr. G. V. Ellis, his successor in the chair of Anatomy in University College; Sharpey editing as before the General Anatomy and the Descriptive Anatomy of the Viscera.

In the Seventh Edition, which was published in 1867, while the General Anatomy continued to be edited by Sharpey, the whole of the Descriptive and Visceral Anatomy was taken in hand by Dr. Allen Thomson, Professor of Anatomy in the University of Glasgow, and by Dr. John Cleland, then Professor in Galway, now the successor of Allen Thomson in Glasgow. This portion of the work was in great measure recast by Cleland, and many new figures from the facile pencil of Allen Thomson were added.

The changes in the Eighth Edition, which was published in 1876, and was the first appearing under the auspices of the present publishers, were still greater. On this occasion most of the Descriptive Anatomy was undertaken by Dr. Allen Thomson, who also contributed a chapter on Embryology, while the account of the Brain and Spinal Cord was placed under the editorship of Dr. W. R. Gowers. The section on General Anatomy and the chapters on the Thoracic, Abdominal and Pelvic Organs, and the Organs of the Senses, were again edited by Sharpey, with the assistance of one of the

present Editors (Professor Schäfer), much of this part of the work being re-written and many new illustrations introduced.

In 1882 the Ninth Edition was published under the editorship of Dr. Allen Thomson, Mr. E. A. Schäfer, then Assistant Professor of Physiology in University College, and Mr. G. D. Thane, the successor of Ellis in the chair of Anatomy. Dr. Allen Thomson undertook the revision of the chapter on Embryology. Professor Thane re-edited the Descriptive Anatomy; while the General Histology and the Special and Minute Anatomy of the Viscera, including the Brain and Spinal Cord, fell to Professor Schäfer.

The preparation of the present Edition was commenced in 1890 by Professors Schäfer and Thane. It was decided to entirely remodel the work, to increase the size of the page and the number of illustrations, and to publish the several parts separately as they might be got ready for press: each part being thus a special treatise on the particular subject denoted by its title, and the whole being intended to form collectively a complete text-book and work of reference in Anatomy. With this end in view a copious Bibliography has been provided for each subject, and the illustrations have been greatly multiplied. Many have been re-drawn upon a larger scale to suit the page, and many original figures have been added, other illustrations having been copied from various monographs and standard works. Little of the original book now remains beyond the title, greater alterations having been made in this than in any previous Edition since 1845.

The first parts to appear (1890) were those on Embryology (Professor Schäfer), and Osteology (Professor Thane). In 1891 the General Anatomy or Histology (Professor Schäfer); and in 1892 the Arthrology, Myology and Angeiology (Professor Thane) were published. In 1893 the Brain and Spinal Cord made its appearance, and in the following year the Organs of the Senses, both the work of Professor Schäfer. A part dealing with the Nerves, undertaken by Professor Thane, was published this summer, and a final part, containing the Anatomy of the Digestive, Respiratory, Urinary and Generative Organs has now been added, thus completing the work. In this part the anatomical descriptions have been allotted to and in many cases entirely re-written by Dr. J. Symington, Professor of Anatomy in Queen's College, Belfast, while the histological portion of the Splanchnology has been re-edited by Professor Schäfer. A chapter on Superficial Anatomy will appear in the form of an Appendix, under the joint editorship of Professor Thane and Mr. R. J. Godlee, M.S., Professor of Clinical Surgery in University College.

The publication in separate parts will, it is hoped, be found convenient to students and others using the work. The parts have been arranged so as to facilitate their being bound up into volumes, although each part is complete with Table of Contents and Index. Most of the labour of

preparing the Index, which also partakes of the nature of a Glossary, has fallen to Mr. T. W. P. Lawrence, M.B., F.R.C.S., Curator of the Museum in University College, who has devoted much time and attention to rendering this important addendum as complete as possible.

The new illustrations in the first and third volumes have mostly been executed by Mr. J. T. Balcomb, who has taken a large amount of pains to meet the requirements of the Editors. The illustrations of the bones and other new figures in the second volume have been engraved by Mr. C. Butterworth, from drawings by Mr. Donald Gunn, Mr. T. W. P. Lawrence, and Professor Thane.

The Editors are indebted to Mr. R. J. Smith for kindly looking through many of the proofs of the final part.

December, 1895.

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ORGANS OF DIGESTION.

BY E. A. SCHÄFER AND J. SYMINGTON.

THE digestive apparatus consists of the alimentary canal, the teeth, and various glands, the secretions of which are discharged through ducts opening into the canal.

The alimentary canal commences at the mouth and terminates at the anus. Its total length is, on an average, about thirty feet.

The part situated in the head, neck, and thorax is comparatively straight, and measures from its commencement at the opening into the mouth to its termination in the stomach about 15 to 18 inches. The rest of the canal lies in the abdomen and pelvis. If this portion extended in a straight line from the œsophageal opening of the stomach to the anus, it would not exceed in length the part above the diaphragm ; but in consequence of its convoluted and tortuous course, it is nearly twenty times as long.

The part of the alimentary canal which lies above the diaphragm consists of the *mouth*, *throat*, and *gullet* ; while that contained in the abdomen and pelvis consists of the *stomach* and the *small* and *large intestines*. Numerous small glands are situated in the wall of the alimentary canal, some in its mucous membrane, and others in its submucous tissue. The larger glands, the ducts of which open into the canal, are the *salivary glands* and the *liver* and *pancreas*. The ducts of the *salivary glands* open into the mouth, and those of the *liver* and *pancreas* into the upper part of the small intestine. Below and behind the tongue the alimentary canal is joined by the wind-pipe. Since the respiratory tract is developed much in the same way as a gland by an outgrowth from the ventral wall of the fore-gut and remains permanently connected with it, the alimentary canal and respiratory organs are often grouped together as the *gastro-pulmonary system*.

THE MOUTH.

The cavity of the mouth opens anteriorly on the face by a transverse aperture called the *rima oris*, while posteriorly it communicates with the pharynx through the fauces (*isthmus faucium*). This cavity is divided into two parts, an outer and an inner, by the alveolar arches and teeth (see fig. 1). The outer part (*vestibulum oris*) is bounded externally by the lips and cheeks, and internally by the teeth and gums, covering the outer aspect of the alveolar processes of the upper and lower jaws. The roof and floor of the vestibule are formed by the reflection of the mucous membrane of the lips and cheek inwards to the alveolar processes, which it joins about the level of the middle of the fangs of the teeth. The extension of the vestibule upwards and downwards external to the gums may be called the *superior* and *inferior alveolo-labial sulci*. Each of these sulci is interrupted in the middle by a small vertical fold of the mucous membrane called the *frænum labii*. The fold connecting the upper lip with the gum is larger than that of the lower lip. The vestibulum oris receives on each side the secretion of the parotid gland. The inner portion of the mouth (*cavum oris*) lies within the concavity of the alveolar arches, and is bounded above by the palate, while in its floor is situated the tongue. It receives the secretions of the submaxillary and sublingual glands.

When the teeth of the upper and lower jaws are in contact, the vestibule of the mouth communicates with the cavity of the mouth proper merely by the narrow

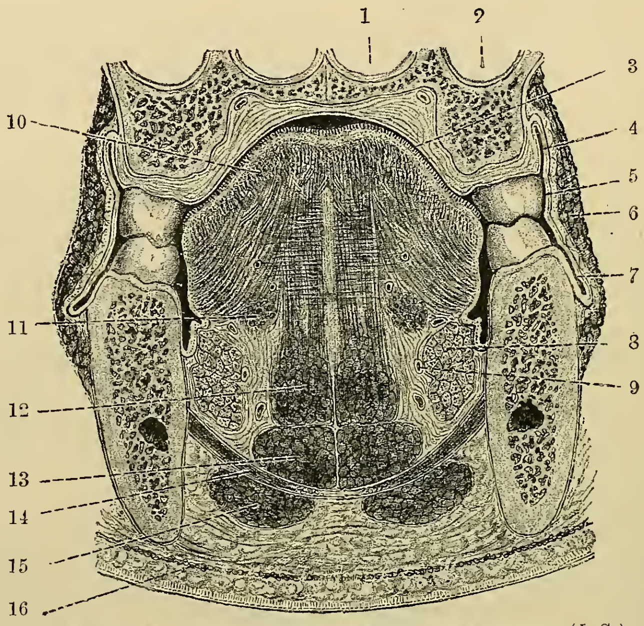
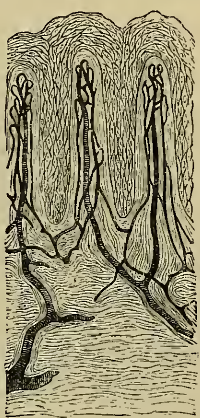


Fig. 1.—CORONAL SECTION OF MOUTH BEHIND THE SECOND MOLAR TEETH. (J. S.) Natural size.

1, nasal fossa ; 2, maxillary antrum ; 3, cavum oris ; 4, superior alveolo-labial sulcus ; 5, vestibulum oris ; 6, buccinator muscle ; 7, inferior alveolo-labial sulcus ; 8, sublingual gland ; 9, duct of Wharton ; 10, superior lingualis muscle ; 11, inferior lingualis ; 12, genio-glossus ; 13, genio-hyoid ; 14, mylo-hyoid ; 15, anterior belly of digastric ; 16, platysma.

clefts between the teeth and a somewhat larger opening placed behind the last molar tooth and in front of the ramus of the jaw.



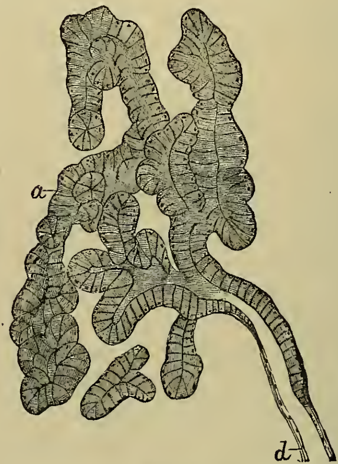


Fig. 2.—THREE PAPILLÆ FROM THE LIP, WITH THE BLOOD-VESSELS INJECTED. (Toldt.)

Fig. 3.—PART OF A SMALL MUCOUS GLAND OF THE MOUTH. (Klein.)
a, alveoli ; *d*, duct

The *lips* and *cheeks* are composed externally of skin, and internally of mucous membrane, between which are included muscles, vessels, and nerves fully described in

other parts of this work, areolar tissue, fat, and numerous small glands. The free border of the lips is protected by a dry mucous membrane, which becomes continuous with the skin, is covered with numerous minute vascular papillæ (fig. 2), and is highly sensitive. In some of these papillæ nerve end-bulbs, approaching in character to tactile corpuscles, are found.

Numerous small racemose glands (*labial glands*) open on the inner surface of the lips near the oral aperture. They are situated between the mucous membrane and the orbicularis oris muscle.

Other small glands (*buccal glands*) lie between the buccinator muscle and the mucous membrane of the cheek. Two or three, larger than the rest, found between the masseter and buccinator muscles, and opening by separate ducts near the last molar teeth, are called the *molar glands*. The secretion of these glands is understood to be mucus; whether it has any of the specific properties of saliva is not known. Small sebaceous glands occur on the outer part of the red border of the lips.

The posterior part of the cheek contains a pad of fat surrounded by a well-defined capsule (see Vol. II., Part 2, p. 293).

Immediately within the lips and cheeks are the *dental arches*, consisting of the teeth, gums, and alveolar borders of the maxillæ. The *gums* (*gingivæ*) are composed of dense connective tissue, cohering very closely with the periosteum of the alveolar processes, and covered by a red and highly vascular mucous membrane, which is smooth in its general surface, but is beset with fine papillæ in the immediate vicinity of the teeth.

The mucous membrane of the mouth is lined by scaly stratified epithelium, the cells of the deeper layers of which are united by intercellular bridges like those of the rete Malpighii of the epidermis.

THE TONGUE.

The **tongue** is a muscular organ, situated in the floor of the mouth and in the anterior wall of the oral portion of the pharynx. It consists of a main portion or

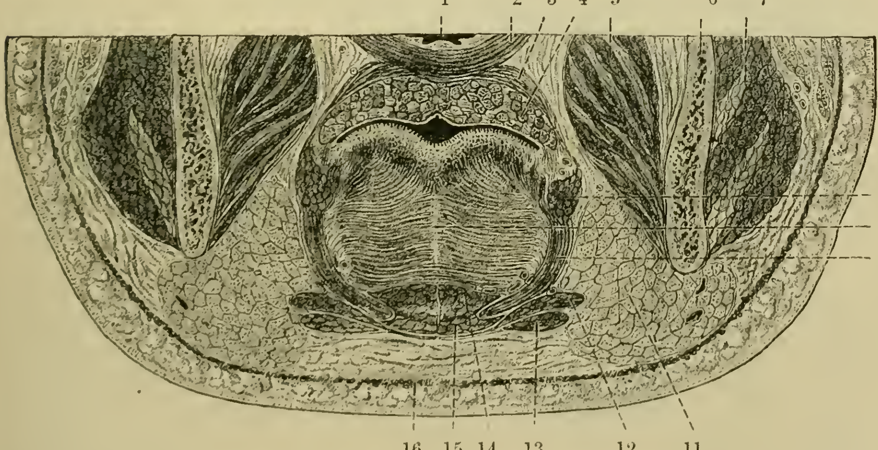


Fig. 4.—Coronal section of the lower part of the face at the isthmus of the fauces. (J. S.) $\frac{2}{3}$

1, pharynx; 2. levator palati; 3, palato-glossus; 4, glands of soft palate; 5, internal pterygoid; 6, ramus of lower jaw; 7, masseter; 8, stylo-glossus; 9, septum linguæ; 10, hyo-glossus; 11, submaxillary gland; 12, mylo-hyoid; 13, digastric; 14, genio-glossus; 15, genio-hyoid; 16, platysma

body, an anterior free extremity or *tip*, and a lower fixed part or *root*, which is attached to the lower jaw and hyoid bone. Its upper or dorsal surface, which is

covered in its entire extent by mucous membrane, is convex from before backwards, and from side to side, with a slight median depression. This surface is in relation with the hard and soft palate, the posterior wall of the pharynx, and the upper part of the anterior surface of the epiglottis (see fig. 18). The under surface is free and covered with mucous membrane in its anterior part only, the larger and posterior portion of this aspect not being free, but connected by various muscles with the lower jaw, hyoid bone, and styloid process. Here also enter its blood-vessels and nerves. The tongue has a free rounded border at its anterior extremity or tip, and at the sides as far back as the last molar tooth, where the border gradually disappears.

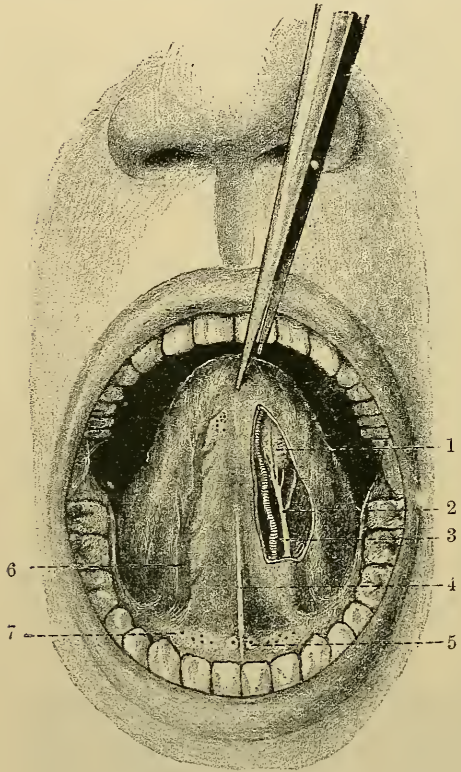


Fig. 5.—View of the under surface of the anterior part of the tongue and of the sublingual portion of the floor of the mouth. (Modified from Testut.) (J. S.)

On the left side part of the mucous membrane of the tongue has been removed, and also some fibres of the inferior lingualis muscle, in order to expose the ranine artery, the lingual nerve, and the glands of Blandin.

1, glands of Blandin; 2, lingual nerve; 3, ranine artery; 4, frænum linguæ; 5, orifice of Wharton's duct; 6, ranine vein, seen through the mucous membrane; 7, mucous membrane covering sublingual gland.

Mucous membrane. — On the under surface of the tongue the mucous membrane is smooth and thin, and in the middle line is raised into a prominent vertical fold, the *frænum linguæ*. In front of the frænum the ranine vein can be distinctly seen on each side through the mucous membrane, and close to it lies the ranine artery. Further out a slight fold of the mucous membrane, *plica fimbriata*, with its free edge notched (see fig. 6), passes from near the tip backwards and outwards. This fold is better marked in the fœtus and child than in the adult; and, according to Gegenbaur, it is a vestige of the under-tongue of the lemurs. From the under surface of the tongue the mucous membrane is reflected towards the inner aspect of the lower jaw, forming the sublingual portion of the floor of the mouth. The deep groove between the tongue and the alveolar process of the jaw may be termed the *alveolo-lingual sulcus*. On each side of the lower and anterior part of the frænum linguæ there is a distinct papilla, at the apex of which is the orifice of the duct of the submaxillary gland (fig. 5, *5*). From this point outwards and backwards for about an inch-and-a-half the mucous membrane is raised into a ridge by the sublingual gland. On this ridge are the openings of small ducts from the sublingual gland (fig. 5, *7*).

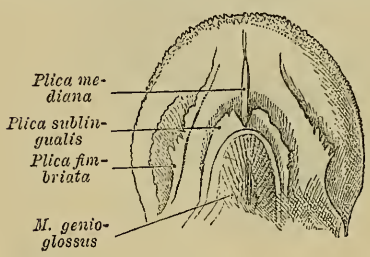


Fig. 6.—Under surface of the tongue of a new-born child. (From Gegenbaur.)

The dorsal surface of the tongue, from its mode of development and the structure of its mucous membrane, presents a natural division into an anterior and a posterior portion. These two portions are frequently separated in the adult by a median recess, the *foramen cæcum*, and a shallow groove (*sulcus terminalis*, His) passing from this outwards and forwards on each side.[1] The anterior portion, forming about two-thirds of the upper or dorsal surface, has its mucous membrane thin, closely adherent to the muscular tissue below, and provided with numerous small eminences named papillæ. These are also found upon the tip and borders, where, however, they gradually become smaller, and towards its under surface they disappear. The mucous membrane on the posterior third of the tongue differs considerably from that covering its anterior two-thirds. It is thicker, smoother, and less adherent, and in

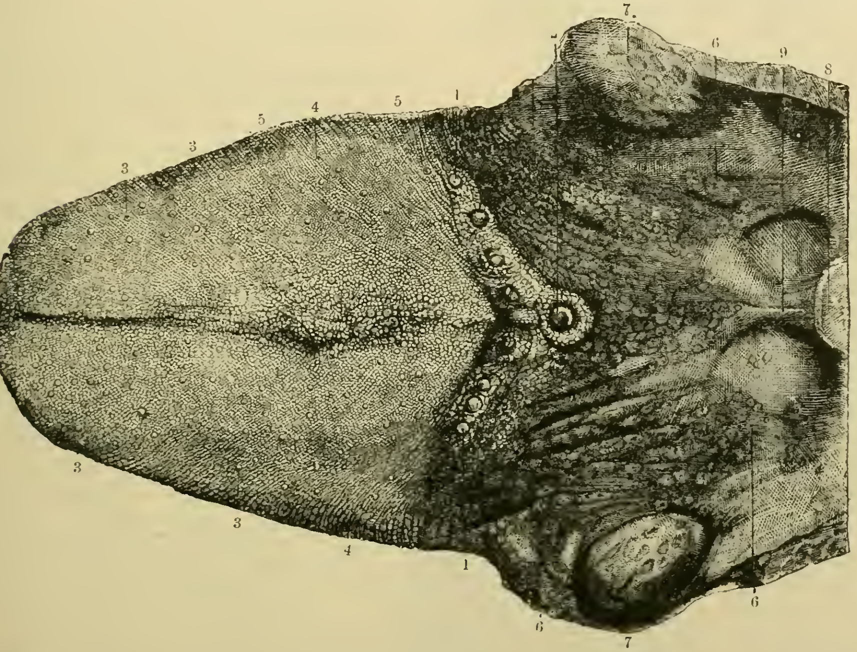


Fig. 7.—Papillary surface of the tongue, with the fauces and tonsils. (From Sappey.)

1, 2, circumvallate papillæ ; behind 2, the foramen cæcum ; 3, fungiform papillæ ; 4, filiform and conical papillæ : 5, transverse and oblique ranges ; 6, mucous glands and lymphoid follicles at the base of the tongue and in the fauces ; 7, tonsils ; 8, tip of the epiglottis ; 9, median glosso-epiglottic fold of frænum epiglottidis.

place of papillæ, is studded with numerous mucous glands and lymphoid follicles. The latter are often called the *lingual tonsils*. Three folds of the mucous membrane, one median and two lateral, named the *glosso-epiglottic folds*, pass backward from the base of the tongue to the epiglottis. Between these folds are the two *glosso-epiglottic fossæ* or *sinuses*. Further forward the mucous membrane is joined on each side by the anterior palatine arch, behind which it is continuous with the mucous membrane covering the tonsils. Except in the neighbourhood of the circumvallate papillæ the papillary surface of the tongue is devoid of glands, but they occur abundantly at the base, sides, and under surface of the organ, and are in structure similar to those which occur elsewhere in the mouth (fig. 3).

The papillæ found on the anterior two-thirds of the tongue are of three kinds, *circumvallate*, *fungiform*, and *conical*, varying both in size and form, but all of them visible to the naked eye ; they themselves, like the rest of the mucous

[1] For their developmental significance, see Vol. I., Part 1, Embryology, p. 102.

membrane of the tongue and mouth generally, are covered with closely set, microscopic secondary papillæ hidden under the epithelium, which correspond with those of the skin, and are each occupied by a long loop of capillary blood-vessels. Lymphatics also originate within the papillæ and pass as elsewhere in the mouth into a superficial plexus in the mucous membrane, from which again the lymph is conveyed away by valved vessels seated in the submucous tissue.

The circumvallate papillæ (fig. 7, *1*, *2*), from 7 to 12 in number, are found at the union of the middle and posterior thirds of the tongue, arranged in two lateral

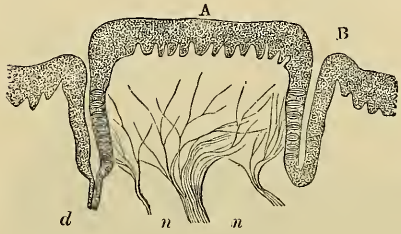


Fig. 8. — VERTICAL SECTION OF CIRCUMVALLATE PAPILLA FROM THE CALF. (Engelmann.) 25 diameters.

A, the papilla ; B, the surrounding wall. The figure shows the nerves of the papilla spreading towards the surface, and towards the taste-buds which are imbedded in the epithelium at the sides ; in the sulcus on the left the duct of a gland is seen to open.

rows, which run obliquely backwards and inwards towards a median papilla, like the arms of the letter V. Not unfrequently there are two papillæ in the middle line. They are situated in cup-like depressions of the mucous membrane, and have the shape of a truncated cone, of which the smaller end is attached to the bottom of the cavity, and the broad flattened base appears on the surface (fig. 8). They are, therefore, surrounded by a circular trench (fossa), around which again is a slight annular elevation of the mucous membrane (vallum). In some of them there is found a central depression. The ducts of one or more serous glands open into the trench of each circumvallate papilla (fig. 8, *d* ; fig. 9, *M*). The stratified epithelium covering the papilla vallata is thick, and completely conceals the minute secondary papillæ.

Taste-buds are found forming a zone around the sides of these papillæ, and in man and some animals upon the opposed wall of the vallum (fig. 9). Their struc-

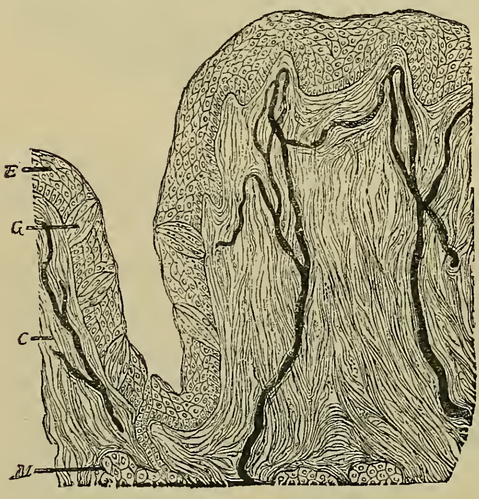


Fig. 9.—SECTION OF CIRCUMVALLATE PAPILLA, HUMAN. THE FIGURE INCLUDES ONE SIDE OF THE PAPILLA AND THE ADJOINING PART OF THE VALLUM. (Magnified 150 diameters.) (Heitzmann.)

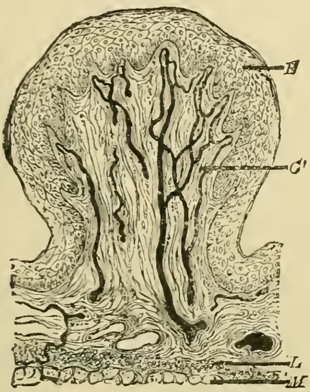
E, epithelium ; *G*, taste-bud ; *C*, corium with injected blood-vessels ; *M*, gland with duct.

ture is given in the part of this work dealing with the sense organs (Vol. III., Part 3, pp. 148-151).

The *fungiform papillæ*, more numerous than the last, are small rounded eminences scattered over the middle and fore part of the dorsum of the tongue (fig. 7, *3*) ; but they are found in greater number and closer together at the apex and near the borders. They are easily distinguished in the living tongue owing to their deep red colour. They are narrow at their points of attachment, but are gradually enlarged towards their free extremities, which are blunt and rounded (fig. 10).

The *conical papillæ* are the most numerous of all, as well as the smallest. They are minute, conical, tapering, or cylindrical eminences, which are densely set over

the greater part of the dorsum of the tongue (fig. 7, *4*), but towards the base gradually disappear. They are arranged in lines diverging from the raphe, at first



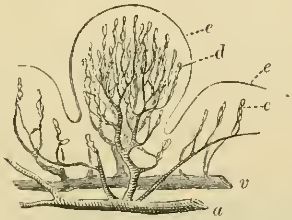


Fig. 10.—SECTION OF FUNGIFORM PAPILLA, HUMAN, WITH THE BLOOD-VESSELS INJECTED. (Heitzmann.) *E*, epithelium ; *C*, corium ; *L*, lymphoid tissue ; *M*, muscular fibres of tongue.

Fig. 11.—A FUNGIFORM PAPILLA WITH THE BLOOD-VESSELS INJECTED. (After Todd and Bowman.) *a*, artery ; *v*, vein ; *c*, capillary loops of simple papillæ in the neighbourhood, covered by the epithelium ; *d*, capillary loops of the secondary papillæ ; *e*, epithelium.

in an oblique direction, like the two ranges of papillæ vallatæ, but gradually becoming transverse towards the tip of the tongue. At the sides they are longer and more slender, and arranged in parallel rows, perpendicular to the border of the tongue.

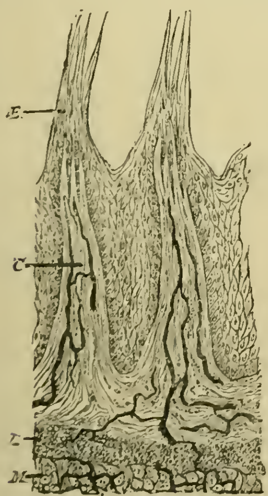


Fig. 12.—SECTION OF TWO FILIFORM PAPILLÆ, HUMAN. (Heitzmann.)
E, epithelium ; *C*, corium ; *L*, lymphoid tissue ; *M*, muscular fibres of tongue.

Fig. 13.—TWO FILIFORM PAPILLÆ, ONE WITH EPITHELIUM AND WITH THE BLOOD-VESSELS INJECTED, THE OTHER WITHOUT. 35 diameters. (After Todd and Bowman.)

p, the substance of the papillæ divided at their upper extremities into secondary papillæ ; *a*, artery, and *v*, vein, connected by capillary loops ; *e*, epithelial covering, laminated between the papillæ, but extended into hair-like processes, *f*, over the secondary papillæ.

The secondary papillæ which are borne by some of the conical papillæ are peculiar both in containing a number of elastic fibres, giving them greater firmness, and in the character of their epithelial covering, which forms a separate horny process over each secondary papilla, greater in length than the papilla which it covers (figs. 12 and 13). Over some of the papillæ these processes form a pencil of fine fibres, as shown in fig. 13; hence the name "filiform" which has been applied to these papillæ.

The papillary surface of the tongue is supplied abundantly with nerves, some of which terminate in end-bulbs, and a few in tactile corpuscles. In the fungiform papillæ the nerves are large and numerous; but they are still more abundant, and of greater size, in the circumvallate papillæ, where they are chiefly distributed in the neighbourhood of the taste-buds (fig. 8).

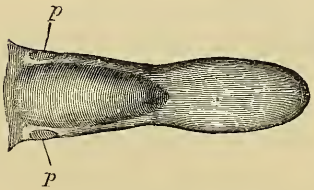


Fig. 14.—Tongue of rabbit, showing the situation of the papillæ foliatæ, *p*.

The papillæ, besides being the parts chiefly concerned in the special sense of taste, also possess, in a very acute degree, tactile sensibility; and the conical and filiform papillæ, armed with their denser epithelial covering, serve a mechanical purpose, in the action of the tongue upon the food, as is well illustrated by the more developed form which these papillæ attain in many carnivorous animals.

In some animals (*e.g.*, rabbit) there is present on each side of the tongue, about opposite the ends of the V formed by the line of papillæ vallatæ, an oval aggregation of transversely placed ridges or laminæ with intervening furrows, which is termed the *papilla foliata* (fig. 14). The ridges are covered with a thick stratified epithelium, and in this epithelium at their sides are embedded numerous taste-buds (fig. 15). There is no definite papilla foliata in the human tongue, but in a situation similar to that in which the papilla foliata of animals occurs the mucous membrane often exhibits a number of low ridges, and is beset with taste-buds.

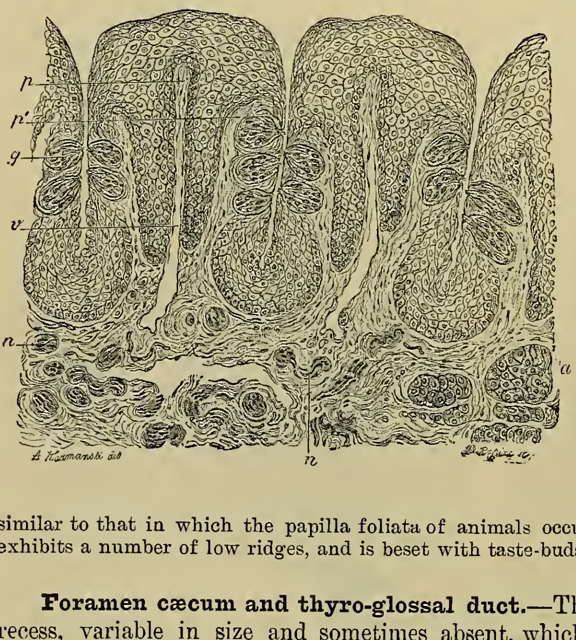


Fig. 15.—Vertical section of papilla foliata of the rabbit, passing across the foliæ. (Ranvier.)

p, central lamina of the corium; *v*, section across a vein, which traverses the whole length of the folia; *p'*, lateral lamina in which the nerve-fibres run; *g*, taste-bud; *n*, sections of nerve-bundles; *a*, serous gland.

Foramen cæcum and thyro-glossal duct.—The foramen cæcum is a median recess, variable in size and sometimes absent, which is situated just behind the median circumvallate papilla. According to His, it represents the apex of a V-shaped depression, which is formed by the development of the tongue from an anterior median process (tuberculum impar), and two lateral and posterior promi-

nences, which grow forwards at the sides of the tuberculum impar. According to the same authority, the foramen cæcum indicates the position of the epithelial outgrowth from which the median portion of the thyroid gland has been formed. As the thyroid recedes from the tongue it becomes connected with the foramen cæcum by a long narrow tube—the *thyro-glossal duct*. The upper part of this duct may persist as a canal (*ductus lingualis*) leading from the foramen cæcum downward to the hyoid bone. Kanthack, on the other hand, holds that no intrinsic connection exists between the development of the tongue and that of the thyroid body. He states that the foramen cæcum is often absent, and when present passes backwards near the surface and never dips down towards the basi-hyoid. In none out of one hundred adults that he examined did he find any trace of a lingual duct, and out of sixty fœtuses, varying in age from two and-a-half to eight months, he never observed the foramen cæcum to extend downwards to the hyoid bone.

Glands.—The mucous membrane of the tongue is provided with numerous small glands (*lingual glands*), collected principally about the posterior part of its upper surface, near the papillæ vallatæ and foramen cæcum, into which last the ducts of several open. These glands have usually been supposed to secrete mucus, but it has been ascertained that some of them, especially those which open in the trenches around the papillæ vallatæ, and at other parts where taste-buds occur, yield a serous secretion (Ebner). Other small glands are found also beneath the mucous membrane of the borders of the tongue. There is, in particular, a group on the under surface of the tongue on each side near the apex called the *glands of Blandin* (see fig. 5). They are there aggregated into a small oblong mass, out of which several ducts proceed and open in a line on the mucous membrane. Most of the glands are acino-tubular.

The mucous membrane of the tongue, at least its posterior part, is largely composed of retiform or lymphoid tissue, which is collected at numerous points into the denser nodular masses known as follicular glands, or lymphoid follicles. The blood-vessels and lymphatics of this part of the membrane are numerous and large, but the papillæ on its surface are comparatively small, and are completely concealed by the thick superjacent epithelium. Here and there the mucous membrane exhibits recesses or crypts (fig. 16, *f*), either simple or surrounded by smaller ones which open into them. The walls of these recesses are generally studded with lymphoid nodules ; and they receive many of the ducts of the mucous glands.

Muscular substance.—The substance of the tongue is chiefly composed of muscular fibres running in various directions. Many belong to muscles which enter at its base and under surface, and attach it to other parts : these are called the *extrinsic muscles* of the tongue (hyo-glossus, chondro-glossus, genio-glossus, palato-glossus, stylo-glossus), and are elsewhere described. Others which constitute the *intrinsic* or *proper muscles*, and are placed entirely within the substance of the organ, will be here more particularly noticed. They are as follows :—

The **superficial lingual muscle** consists mainly of longitudinal fibres, placed near the upper surface of the tongue, immediately beneath the mucous membrane, and is traceable from the apex of the organ backwards to the hyoid bone (fig. 17, *10* ; fig. 16, *l s*). The individual fibres do not run the whole of this distance, but are attached at intervals to the submucous and glandular tissues. The entire layer becomes thinner towards the base of the tongue, near which it is overlapped at the sides by a thin plane of oblique or nearly transverse fibres derived from the palato-glossus and hyo-glossus muscles.

The **inferior lingual muscle** consists of a rounded muscular band, extending along the under surface of the tongue from base to apex, and lying outside the genio-glossus, between that muscle and the hyo-glossus (fig. 17, *6*). Posteriorly, some of its fibres are lost in the substance of the tongue, and others reach the hyoid

bone. In front, having first been joined, at the anterior border of the hyo-glossus muscle, by fibres from the stylo-glossus, it is prolonged beneath the border of the tongue as far as its point.

The **transverse** muscular fibres of the tongue (fig. 17, *2* ; fig. 16, *t r*) form together with the intermixed fat a considerable part of its substance. They are found in the

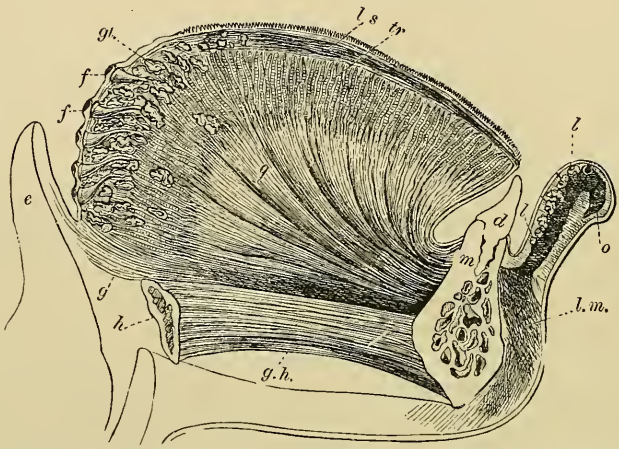


Fig. 16.—Longitudinal vertical section of the tongue, lip, &c. (From Kölliker and Arnold.)

m, symphysis of the lower jaw ; *d*, incisor tooth ; *h*, hyoid bone ; *g h*, genio-hyoid muscle ; *g*, genio-hyo-glossus spreading along the whole of the tongue ; *t r*, transverse muscle ; *l s*, superior longitudinal muscle ; *g l*, lingual glands ; *f*, lymphoid crypts ; *e*, epiglottis ; *l*, section of the lip and labial glands ; *o*, cut fibres of the orbicularis oris ; *l m*, levator menti.

interval between the upper and lower longitudinal muscles, and they are interwoven extensively with the other muscular fibres. Passing outwards from the median plane, where they take origin from a fibrous septum (fig. 17, *3*), they reach the dorsum and borders of the tongue. In proceeding outwards, they separate, and the superior fibres incline upwards, forming a series of curves with the concavity upwards.

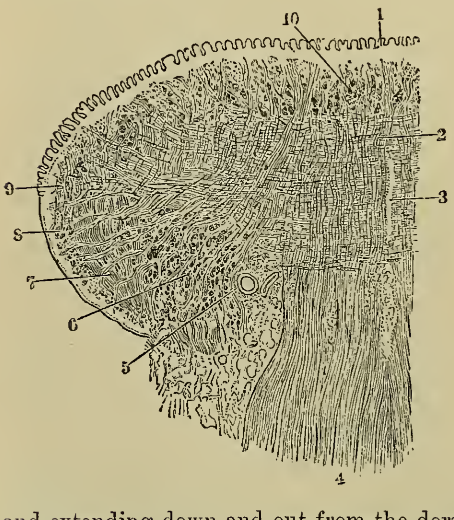


Fig. 17.—Coronal section of the tongue about the middle of its length, left half seen from behind. (W. Krause.)

1, papillæ on the dorsal surface ; 2, transverse muscular fibres ; 3, septum linguæ ; 4, genio-glossus ; 5, ranine artery ; 6, inferior lingualis ; 7, hyo-glossus ; 8, vertical muscular fibres ; 9, stylo-glossus ; 10, superficial lingual muscle.

The fibres of the palato-glossus muscle are stated by Zaglas and Henle to be continuous with fibres of the transverse set.

Vertical fibres (external perpendicular muscle of Zaglas), decussating with the transverse fibres and the insertions of the genio-glossus (fig. 17, *8*), form a set of curves in each half of the tongue with their concavity outwards, and extending down and out from the dorsum to the under surface of the border, so that those which are outermost are shortest.

Examined in transverse sections, the muscular fibres are seen to be arranged so as to render the substance divisible into an outer part or *cortex* and an internal or *medullary part*. The fibres of the cortex are principally longitudinal, derived superiorly from the lingualis superior, further outwards from the hyo-glossus, on the side from the stylo-glossus, and beneath this from the lingualis inferior. They ensheath the medullary part on all sides except inferiorly, where the genio-glossi muscles enter it between the inferior linguales. In the medullary part are found, embedded in fat, the decussating fibres of the transverse muscle passing across, the genio-glossi radiating upwards and outwards, and the vertical muscles arching downwards and outwards. In addition to the movements which may be given to the tongue by the extrinsic muscles, this organ is capable of being curved upwards, downwards, or laterally by its cortical fibres, it is flattened by the vertical fibres, and its margins are again drawn together by the transverse whilst the two last mentioned, acting together, would tend to lengthen the organ.

The **septum** of the tongue is a thin fibrous partition which extends forwards from the hyoid bone to the tip, and divides one half of the medullary part of the tongue from the other, but does not penetrate into the cortex.

Vessels and nerves.—The **arteries** of the tongue are derived from the lingual, with some small branches from the facial and ascending pharyngeal. The veins empty their contents into the internal jugular trunk.

The **nerves** of the tongue (exclusive of branches from the sympathetic nerves) are five, viz., the *lingual* branch of the *fifth* pair, which supplies the papillæ and mucous membrane of the fore part and sides of the tongue to the extent of about two-thirds of its surface with common sensibility ; the *chorda tympani*, which accompanies the lingual to the tongue and probably serves as the nerve of taste to a corresponding area of the mucous membrane ; the lingual branch of the *glosso-pharyngeal*, which sends filaments, both sensory and gustatory, to the mucous membrane at the base of the tongue, and especially to the papillæ vallatæ ; the *superior laryngeal*, which distributes a few sensory branches in the neighbourhood of the epiglottis ; and lastly, the *hypoglossal* nerve, which is distributed to the muscles. Microscopic ganglia exist upon the expansions of the glosso-pharyngeal nerve, especially in the neighbourhood of the papillæ vallatæ and papillæ foliatæ, and they have also been found in the sheep and calf upon the gustatory division of the fifth.

Lymphatics.—The chief lymphatic trunks accompany the ranine vessels, and after traversing one or two small lymphatic glands, seated on the hyo-glossus muscle, pass into the deep cervical glands. Others pass through the mylo-hyoid muscle to the submaxillary lymphatic glands.

The detailed description of the blood-vessels will be found in Vol. II., Part 2, and of the nerves in Vol. III., Part 2.

THE PALATE.

The roof of the mouth is formed by the palate, which consists of two portions ; the fore part being named the hard palate and the back part the soft palate. As a whole, the palate is concave from before backwards, and also from side to side.

The **hard palate** is bounded in front and at the sides by the alveolar arches and gums, and is distinguished from the soft palate by having an osseous framework, already described (see Vol. II., Part 1). It is covered by periosteum and mucous membrane, these two structures being firmly connected together. In front the mucous membrane is thick, dense, rather pale, and corrugated, but it becomes thinner, smoother, and of a deeper colour behind. The corrugations of the mucous membrane—*palatal rugæ*—may be divided into the longitudinal and the transverse. In the middle line there is a longitudinal ridge or raphe, ending behind the interval between the two mesial incisors in a small eminence, the *papilla palatina* or

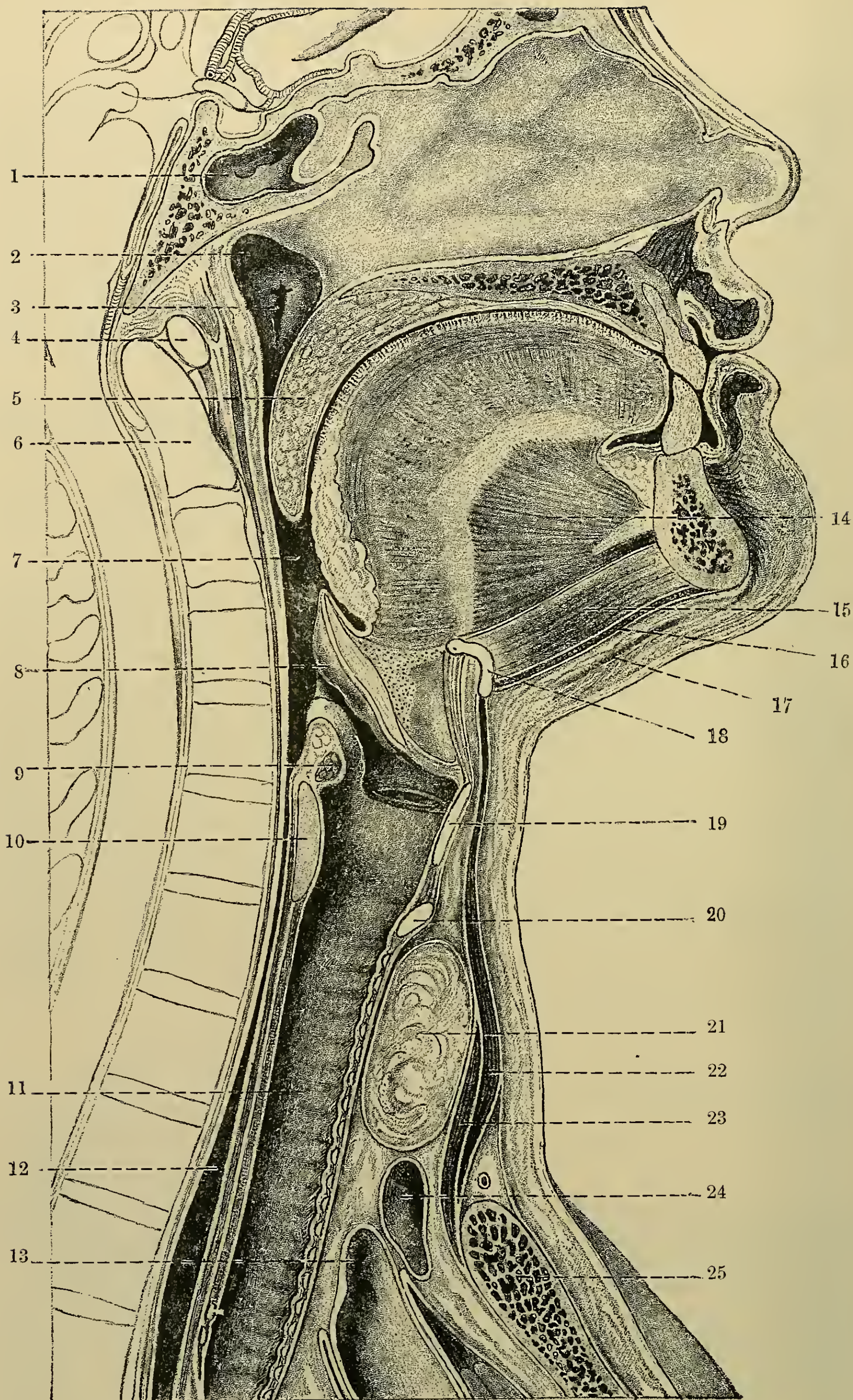


Fig. 18.—Median section of the head and neck. (Braune.) $\frac{2}{3}$

1, sphenoidal sinus ; 2, lateral recess of pharynx ; 3, pharyngeal orifice cf Eustachian tube ; 4, anterior arch of atlas ; 5, soft palate ; 6, body of axis ; 7, oral portion of pharynx ; 8, epiglottis ; 9, arytenoid muscle ; 10, cricoid cartilage ; 11, trachea ; 12, œsophagus ; 13, origin of innominate artery from aorta ; 14, genio-glossus muscle ; 15, genio-hyoid muscle ; 16, mylo-hyoid muscle ; 17, platysma ; 18, hyoid bone ; 19, thyroid cartilage ; 20, cricoid cartilage ; 21, isthmus of thyroid body ; 22, sterno-hyoid ; 23, sterno-thyroid ; 24, left innominate vein ; 25, manubrium sterni.

incisive pad. This papilla corresponds to the anterior palatine fossa, and receives the terminal filaments of the naso-palatine and anterior palatine nerves. Two small blind recesses, one on either side, are sometimes found upon it. They represent the lower part of the naso-palatine foramina or canals of Stensen, which in many animals lead from the mouth into the nose. The transverse rugæ, generally about five or six in number, vary considerably in their development. They are much better marked and more regular in the fœtus (Gegenbaur). In the adult the ridges are often broken up into several small eminences.

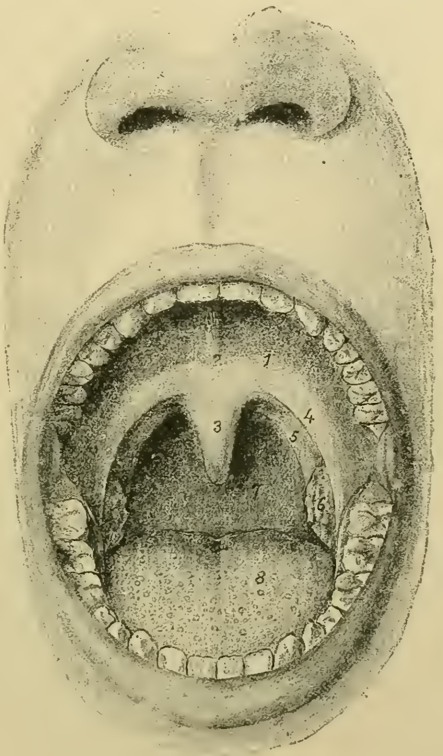


Fig. 19.—View of the soft palate and isthmus faucium from before. (J. S.)

1, soft palate ; 2, its raphe ; 3, uvula ; 4, anterior, and 5, posterior pillar of fauces ; 6, tonsil ; 7, posterior wall of pharynx ; 8, dorsum of tongue.

The **soft palate** (*velum pendulum palati*) is formed by a duplication of mucous membrane, including muscular fibres and numerous glands. It extends from the hard palate backwards and downwards between the nasal and oral portions of the pharynx, and ends below in a free border, which in the middle is prolonged as a conical process, the uvula, while at the sides it is continuous with the posterior pillar of the fauces. As a rule it is about 10 to 12mm. in thickness, nearly half of which is due to the glandular tissue situated between the muscles and the mucous membrane of the anterior or under surface of the velum. This membrane, which is visible from the mouth, is thinner and redder than that of the hard palate, but like it, is covered with a scaly stratified epithelium. The median ridge or raphe, which is continued backwards from the hard palate to the base of the uvula, indicates the original separation of the palate into two lateral halves. The posterior or upper surface of the soft palate is convex and continuous in front with the floor of the nasal fossæ. This surface is covered with ciliated columnar epithelium, while on the under aspect and free margin the epithelium is scaly and stratified.

On both surfaces of the velum are found numerous small compound glands. They particularly abound on the under surface, where they form almost a complete layer under the mucous membrane ; they are also very abundant in the uvula.

In the new-born child the whole posterior surface is covered with ciliated epithelium, but this becomes subsequently replaced by squamous ; the epithelium of the gland-ducts, however, retains in many instances its ciliated character (Klein).

The muscles of the soft palate are described in Vol. II., Part 2.

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THE SALIVARY GLANDS.

The saliva, which is poured into the mouth, and there mixed with the food during mastication, is secreted by three pairs of glands, named from their respective situations, *parotid*, *submaxillary*, and *sublingual*. Agreeing in their general physical characters and structure, these glands differ in their size, form, and position.

The Parotid Gland.—The parotid (fig. 20, *p*) is the largest of the three salivary glands. It lies on the side of the face, in front of the ear, and extends deeply into the space behind the ramus of the lower jaw. Its weight varies from five to eight drachms (20 to 30 grammes).

Its outer surface is convex and lobulated, and is covered by the skin and fascia, and partially by the platysma muscle. It is bounded above by the zygoma, below by a line drawn backwards from the lower border of the jaw to the sterno-mastoid

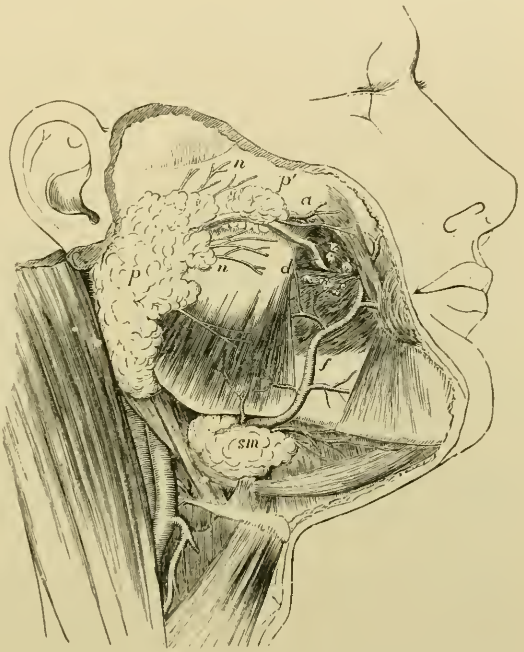

Fig. 20.—Sketch of a superficial dissection of the face, showing the position of the parotid and submaxillary glands. (Allen Thomson.) $\frac{2}{5}$.

p, parotid gland; *p'*, socia parotidis; *d*, the duct of Stensen before it perforates the buccinator muscle; *a*, transverse facial artery; *n*, *n*, branches of the facial nerve emerging from below the gland; *f*, the facial artery passing out of a groove in the submaxillary gland and ascending on the face; *sm*, superficial portion of the submaxillary gland.

muscle, and behind by the external meatus of the ear, the mastoid process, and sterno-mastoid muscle. Its anterior border, which lies over the ramus of the lower jaw, is more irregular, and stretches forwards to a variable extent on the masseter muscle. It is from this anterior border of the gland that the excretory duct passes off; and there is frequently found in connection with the duct, and lying upon the masseter muscle, a small process or a separated portion of the gland (*p'*), which is called *glandula socia parotidis*. On trying to raise the deeper part of the parotid gland from its position, it is found to extend far inwards, between the mastoid process and the ramus of the jaw, towards the base of the skull, and to be intimately connected with several deep-seated parts. Thus, above, it reaches into and occupies the posterior part of the glenoid cavity; behind and below, it touches the digastric muscle, and rests on the styloid process and styloid muscles; and, in front, under cover of the ramus of the jaw, it advances a certain distance between the external and internal pterygoid muscles.

The internal carotid artery and internal jugular vein are close to the deep surface of the gland. The external carotid artery, accompanied by the temporo-maxillary vein, passes through the parotid gland, and in that situation divides into the temporal and internal maxillary arteries, the former soon giving off its auricular and transverse facial branches. The gland is also traversed by the facial nerve, which

divides into branches within its substance, and it is pierced by branches of the great auricular nerve, while the auriculo-temporal nerve ascends beneath its upper and posterior part.

The **parotid duct**, named also **Stensen's duct** (*d. Stenonianus*), appears at the anterior border of the gland, about one finger's breadth below the zygoma, and runs forwards over the masseter muscle, accompanied by the socia parotidis, when that accessory portion of the gland exists, and receiving its ducts. At the anterior border of the masseter, the duct (*d*) turns inwards through the fat of the cheek and pierces the buccinator muscle ; and then, after running for a short distance obliquely forwards beneath the mucous membrane, opens upon the inner surface of the cheek, by a small orifice on a papilla opposite the crown of the second molar tooth of the upper jaw. Its direction across the face may be indicated by a line drawn from the lower margin of the concha of the ear to a point midway between the red margin of the lip and the ala of the nose. The length of the Stenonian duct is about two inches and a half (62 mm.), and its diameter rather less than $\frac{1}{8}$th of an inch (3 mm.). At the place where it perforates the buccinator, its canal is as large as a crowquill, but at its orifice it is smaller than in any other part, and will only admit a fine probe.

Blood-vessels and nerves.—The vessels of the parotid gland enter and leave it at numerous points. The arteries are derived directly from the external carotid, and from those of its branches which pass through or near the gland. The veins correspond. The lymphatics join the deep and superficial set in the neck ; and there are often one or more lymphatic glands embedded in the substance of the parotid. The nerves come from the sympathetic plexus on the external carotid artery, and also from the facial, the auriculo-temporal and great auricular nerves. In the dog and cat it has been experimentally shown that the parotid derives its cerebro-spinal nerve-supply from the glosso-pharyngeal, through the lesser superficial petrosal nerve and the otic ganglion, the fibres finally passing to the gland by a branch of the auriculo-temporal.

VARIETIES.—An instance is recorded by Gruber of a remarkable displacement of the parotid on one side ; the whole gland being situated on the masseter muscle as if it were an enlarged socia parotidis (Virchow's Archiv, xxxii.). Its absence has also been recorded by Poirier (Bulletins de la société anat. de Paris, 1888).

The submaxillary gland.—The submaxillary gland (fig. 4, *11* ; fig. 20, *sm*), the next in size to the parotid, is of a spheroidal form, and weighs about 2 or $2\frac{1}{2}$ drachms (8 to 10 grammes). It is situated immediately below the base and the inner surface of the inferior maxilla, and above the digastric muscle. In this position (fig. 4, *11*) it is covered by the skin, fascia, and platysma myoides, and its inner surface rests on the mylo-hyoid, hyo-glossus, and stylo-glossus muscles ; above, it corresponds with a depression on the inner surface of the jaw-bone ; and it is separated behind from the parotid gland merely by the stylo-maxillary ligament. The facial artery, before it mounts over the jaw-bone, lies in a deep groove upon the back part and upper border of the gland ; while the vein is placed on the superficial surface of the gland.

The duct of the submaxillary gland, named **Wharton's duct** (*d'*, fig. 21), which is about two inches (50 mm.) in length, leaves the main gland posteriorly, together with a thin process of the glandular substance, and passing round the posterior border of the mylo-hyoid muscle (*mh*), runs forwards and inwards above that muscle, between it and the hyo-glossus and genio-glossus, and beneath the sublingual gland, to reach the side of the frænum linguæ. Here it terminates, close to the duct of the opposite side, by a narrow orifice, which opens at the summit of a soft papilla (fig. 5, *5*) seen beneath the tongue. The obvious structure of this gland is like that

of the parotid ; but its lobes are larger, its surrounding areolar web is finer, and its attachments are not so firm. Moreover, its duct has much thinner coats than the parotid duct.

Blood-vessels and nerves.—The blood-vessels of the submaxillary gland are branches of the facial and lingual arteries and veins. The nerves include those derived from the submaxillary ganglion, and through this from the chorda tympani, from the lingual branch of the inferior maxillary (and in rare cases from the mylo-hyoid branch of the inferior dental nerve), and from the sympathetic.

VARIETIES.—Gruber (Virchow's Archiv, Bd. cii.) has recorded a case of complete absence of both submaxillary glands.

The sublingual gland.—The sublingual gland (fig. 1, *8*, and fig. 21, *sl*), the smallest of the salivary glands, is of a narrow oblong shape and weighs scarcely one drachm (4 grammes). It is situated along the floor of the mouth, where it forms a ridge between the tongue and the gums of the lower jaw, covered only by the mucous membrane. It extends from the frænum linguæ in front, where it is in contact with the gland of the opposite side, obliquely backwards and outwards for rather more than an inch and a half. On its inner side it rests on the genio-glossus ;

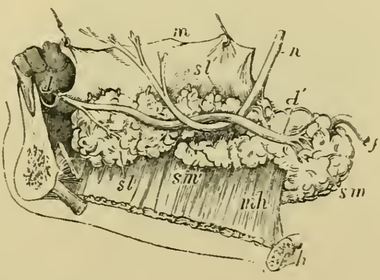

Fig. 21.—VIEW OF THE RIGHT SUBMAXILLARY AND SUBLINGUAL GLANDS FROM THE INSIDE. (Allen Thomson.)

Part of the right side of the jaw, divided from the left at the symphysis, remains ; the tongue and its muscles have been removed ; and the mucous membrane of the right side has been dissected off and hooked upwards so as to expose the sublingual glands ; *s m*, the larger superficial part of the submaxillary gland ; *f*, the facial artery passing through it ; *s m'*, deep portion prolonged on the inner side of the mylo-hyoid muscle *m h* ; *s l*, is placed below the anterior large part of the sublingual gland, with the duct of Bartholin partly shown ; *s l'*, placed above the hinder small end of the gland, indicates one or two of the ducts perforating the mucous membrane ; *d*, the papilla, at which the duct of Wharton opens in front behind the incisor teeth ; *d'*, the commencement of the duct ; *h*, the hyoid bone ; *n*, the lingual nerve ; close to it is the submaxillary ganglion.

below, it is supported by the mylo-hyoid muscle (*mh*), which is interposed between it and the main part of the submaxillary gland ; and it is here in close contact with the Whartonian duct, with the accompanying deep portion of the last-named gland, and also with the lingual branch of the fifth nerve.

The lobules of the sublingual gland are not so closely united together as those of the other salivary glands, and the ducts from many of them open separately into the mouth, along the ridge which indicates the position of the gland. These ducts, named **ducts of Rivinus,** are from eight to twenty in number. Some of them open into the duct of Wharton. One, longer than the rest (which is occasionally derived in part also from the submaxillary gland), runs along the Whartonian duct, and opens either with it or very near it ; this has been named the *duct of Bartholin*, but it is inconstant in its occurrence (Chievitz, Suzanne).

Blood-vessels and nerves.—The **blood-vessels** of this gland are supplied by the sublingual and submental arteries and veins. The **nerves** are numerous, and are derived from the lingual branch of the fifth, the chorda tympani and the sympathetic.

STRUCTURE OF THE SALIVARY GLANDS

These glands are constructed on the compound racemose type (see Vol. I., Part ii., p. 399). Their ducts (traced backwards), after branching a certain number

of times, terminate in fine ramuscules, into which the alveoli open. The *alveoli* of the salivary glands do not always present the form usually regarded as typical of the alveoli of a compound racemose gland. They are sometimes dilatations of the

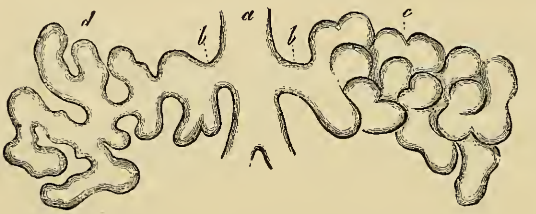

Fig. 22.—Diagram of the construction of a lobule of a tubulo-racemose (acino-tubular) mucous gland. (From Kölliker.)

a, duct; *b*, a branch of the duct; *c*, alveoli as they lie together in the gland; *d*, the same separated, showing their connection as an irregular tube.

extremities of the duct beset with saccular enlargements, sometimes more tubular and even somewhat convoluted without marked sacculation (fig. 22) (acino-tubular variety), but there is no essential difference between the two forms, transitions being met with between them. The alveoli are enclosed by a basement membrane, which is not complete as in some glands, but forms a basket-

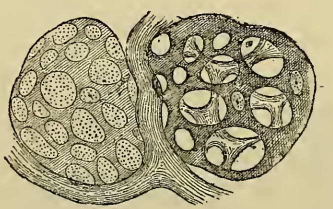

Fig. 23.—Membrana propria of two alveoli isolated. (Heidenhain, after Lavdovsky.)

The preparation is taken from the orbital gland of the dog, which is similar in structure to a mucous salivary gland.

like investment to the alveolus, the flattened cells which form it being ramified and united together by their branches (fig. 23). There is, however, in addition a delicate homogeneous substance occupying the meshes between the cells (see the left-hand alveolus in fig. 23). The cells of the basement membrane are said to send inwards processes to form a sustentacular network amongst the alveolar cells.

The alveoli are united by the blood-vessels and a small amount of loose connective

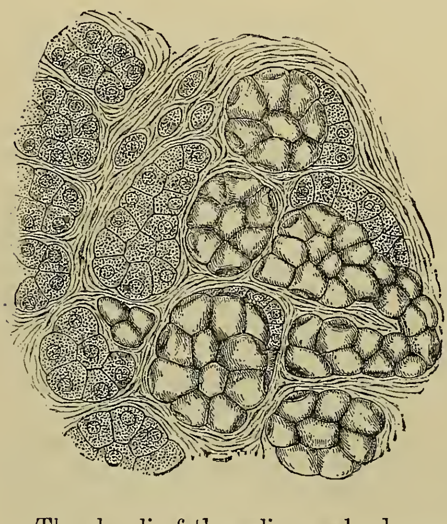

Fig. 24.—Section of part of the human submaxillary gland. (Heidenhain.)

To the right of the figure is a group of mucous alveoli, to the left a group of serous alveoli.

tissue into lobules, and these again by a larger quantity of the same tissue into larger lobules. A considerable amount of connective tissue also accompanies the blood-vessels and duct in their ramifications through the gland. The connective tissue, where it is in larger amount, is lamellar in character (Klein), and it contains, besides the ordinary flattened cells, a certain number of granular plasma-cells and lymph-corpuscles, with fat cells occasionally.

The alveoli of the salivary glands may be divided into two classes, according to the nature of their secretion :—those of the one kind yielding a ropy secretion characterised by containing mucin, and those of the other kind, a thinner more watery secretion, sometimes containing a considerable amount of serum-albumin, so-

that the secretion coagulates on being heated. The two kinds of alveoli may accordingly be distinguished as *mucous* and *serous* or *albuminous* (Heidenhain); they differ from one another both in appearance and in the nature of their secreting cells. In some cases an alveolus may contain mucous and serous cells side by side.

The human parotid and that of all mammals is composed of serous alveoli, and the sublingual gland of mucous alveoli, but in man the submaxillary is a mixed gland, containing both kinds of alveoli, although the serous are the more numerous (fig. 24). In the dog and most other animals it is purely a mucous gland, and in the rabbit and guinea pig it is purely a serous gland. Similar differences have already been noticed (p. 9) in the small glands of the tongue. According to Bermann a gland of tubular structure and furnishing a mucous secretion may also be found attached to the submaxillary in man, and opening into Wharton's duct. In the guinea-pig and rabbit there are small flat mucous glands of tubular structure connected both to the parotid and submaxillary, one to each, and sending

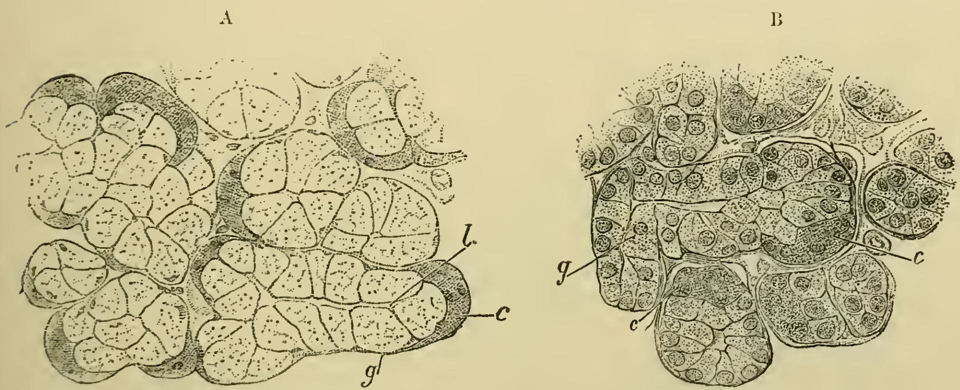

Fig. 25.—Sections of the submaxillary gland of the dog. A, during rest. B, after a period of activity. (Ranvier.)

In A, most of the cells of the alveoli are large and clear, being filled with the material for secretion (in this case, mucigen) which obscures their protoplasm, but some of the cells are small and protoplasmic, forming a crescentic group seen in most of the alveoli.

In B, the accumulated material (mucigen) is discharged from the mucin-secreting cells, which appear in consequence shrunken and less clear. Both the cells and the alveoli are much smaller, and the protoplasm of the cells is now more apparent. The marginal cells of Gianuzzi are enlarged.

c, "crescent" cells; *g*, mucus-secreting cells; *l*, lumen of alveolus.

their ducts to open into the ducts of those glands (*admaxillaries*, Klein). Similar tubular glands have been described in various other animals, and, as above mentioned, also in man. They are most frequently found in connection with the submaxillary, where they form usually a glandular mass distinguishable to the naked eye, and termed by Ranvier the *retro-lingual gland*. Ranvier states, however, that he has not found this in the rabbit, hare, horse and sheep, or in man, but it occurs constantly in all other animals examined.

Mucous alveoli.—In the mucous glands and mucous alveoli of mixed glands most of the alveolar cells, when the gland is in the inactive condition, appear large, clear, and almost spheroidal in shape, and nearly fill the alveoli, which are distended by the cells (right-hand side of fig. 24). The nucleus of each cell is in the part of the cell next to the basement membrane, against which it is generally flattened, and the cells may cause the basement membrane to be bulged out opposite to them. In preparations hardened in alcohol the cells are finely granular, and with the exception of the part around the nucleus are scarcely stained by carmine (fig. 25, A).

When the cells of the mucous alveoli are isolated, they not unfrequently exhibit

processes, one from the base of each cell: the projection is flattened and overlaps the base of a neighbouring cell (Kölliker). The peculiar clear appearance of these cells is due to the accumulation within them of mucin (or of a substance "mucigen" from which mucin is formed). When fragments of the fresh mucous glands are examined in solutions of salt of a certain strength, it may be seen that the clear material which is accumulated within the cells is in the form of minute globules (Langley). When swollen by the addition of water, these run together, and the cell

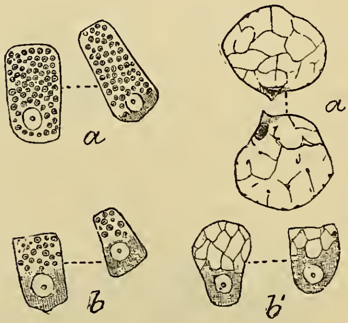

Fig. 26.—Isolated mucin-secreting cells from the submaxillary gland of a dog. (Langley.)

a and *b*, isolated in 2 p. c. salt solution; *a*, from loaded gland; *b*, from discharged gland; *a'*, *b'*, similar cells after treatment with dilute acid.

then appears distended with clear secretion, with threads of protoplasm intersecting it (see fig. 26).

Besides the "mucin cells" there are met with in most alveoli of these glands, cells of a different character, which from their position may be named "marginal cells." In some mucous glands, *e.g.*, the submaxillary of the cat, they form an almost complete outer layer, next to the basement membrane, and enclosing the mucin-cells, but in the dog's submaxillary gland they occur only in small semilunar masses (*lunulæ* or *crescents* of Gianuzzi) at the bottom of the alveoli, flattened up between the basement membrane and the mucin-cells (fig. 25, A; fig. 28, *s*). These marginal cells are small and granular, and stain deeply with carmine and hæmatein.

If the mucous glands are stimulated to secretion, the mucin-cells become gradually smaller and less clear, their contents being exuded in the form of mucus, which first fills the cavity of the alveolus and then passes on into the duct. At the same time the cells are easily stained with carmine and their nuclei are no longer

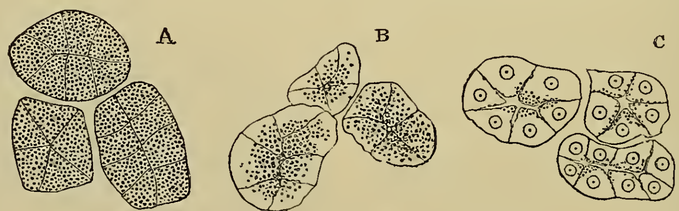

Fig. 27.—Alveoli of serous glands. A, at rest. B, after a short period of activity. C, after a prolonged period of activity. (Langley.)

flattened, but assume a more rounded form and central position (fig. 25, B). If the gland be strongly urged to activity, as by prolonged stimulation of its cerebral nerves, the mucin-cells may undergo still more profound alterations, and may even, according to Heidenhain, become partially or wholly disintegrated, but probably the cell is normally never destroyed. It is possible, however, that, in extreme salivation, some of the mucin-cells are occasionally destroyed, but whether the marginal cells multiply and become filled with secretion, and thus serve to replace the mucin-cells which are lost is doubtful, for it is rare to find evidence of cell-division during functional activity of the gland.

Serous alveoli.—In the serous glands and serous alveoli of mixed glands, the cells, in the inactive condition of the glands, are in the fresh condition and in osmic

preparations seen to be packed full of distinct granules, of an albuminous nature, which obscure their nuclei (Langley). The granules are imbedded in the protoplasm of the cells and the latter almost completely fill the alveoli, scarcely any lumen being discernible (fig. 27, A).

After a short period of activity the granules are found to have disappeared in the outer part of the cell, the inner part being still distinctly granular, and some of the granules are apparently free within the lumen of the alveolus, now becoming distinct (fig. 27, B). With more prolonged activity (fig. 27, C) the clear outer part increases in extent, and the granules are found only in the part of the cell which is close to the lumen, and in those parts which are contiguous to the adjacent cells (corresponding perhaps to fine capillary clefts which pass from the cavity of the alveolus between the cells). The nuclei have now become distinct, and the cells are smaller. We may suppose therefore that the granules, which no doubt contain the specific elements of the secretion, are formed by or from the protoplasm of the cells during rest, and are discharged into the lumen and dissolved during activity. Probably however even during activity new granules are constantly being formed

Fig. 28.—Section of the submaxillary gland of the dog, showing the commencement of a duct in the alveoli. Magnified 425 diameters. (E. A. S.)

a, one of the alveoli, several of which are in the section shown grouped around the commencement of the duct, *d'*; *a'*, an alveolus, not opened by the section; *b*, basement membrane in section; *c*, interstitial connective tissue of the gland; *d*, section of a duct which has passed away from the alveoli, and is now lined with characteristically-striated columnar cells; *s*, semilunar group of darkly-stained cells at the periphery of an alveolus.

and passed onwards towards the lumen. According to Langley, the three processes of growth of the clear protoplasm, conversion of this into granules, and discharge of these into the lumen, are all proceeding simultaneously in different parts of the cell during activity.

In glands which have been hardened in alcohol the granules are no longer seen, their place being occupied by a clear substance which does not stain with carmine.

Ducts.—In the serous glands, and serous parts of mixed glands, the first or *intercalary part* of the duct which conveys the secretion from the alveoli is narrow, and lined with clear flattened cells with elongated nuclei. After a longer or shorter course, this part passes by a somewhat narrower neck, lined with cubical cells with small nuclei, into the intralobular ducts (Klein).

In the mucous glands the intercalary ducts are also lined (fig. 28, *d'*) with clear cells continuous with the cells of the alveoli, but flattened against the basement membrane so as to leave a considerable lumen.

This first part of the duct is generally shorter than the corresponding part in the serous glands, and is regarded by Klein as representing only the part by him termed the "neck"; more probably, however, it must be looked upon as representing both parts, although they are not here so clearly differentiated. The intercalary part of the ducts is described by Klein as being lined, within the

epithelium, by a special delicate nucleated membrane, which in some animals is continued into the intralobular ducts.

In the next or *intralobular part* of the duct (fig. 28, *d*) the character of the epithelium changes abruptly, the cells becoming large and columnar or conical, the

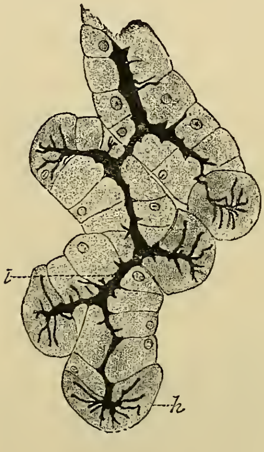

Fig. 29.—Section of alveoli of sublingual gland, human, prepared by Golgi's silver chromate method. (E. Müller.)

l, lumen, stained, showing lateral diverticula proceeding between and also into the cells of the alveoli ; *h*, diverticula penetrating into "crescents."

rounded or truncated apex being directed towards the lumen of the tube. Each cell contains a spherical nucleus near the centre (fig. 28). The part of the cell next the lumen of the duct is granular in character, whereas the part nearest the basement membrane is finely striated longitudinally. This striated appearance is most distinct in the ducts of the submaxillary gland; it is due to the presence of a rod-like or fibrillar structure in that part of the cell.

The lumen of the ducts is continued directly into the alveoli, and its course there can be traced both by injection and in preparations stained by the silver chromate method. By the latter method it has been shown that diverticula extend between the cells of the alveoli, and minute channels are also traceable for a short distance into the protoplasm of the cells. In the mucous alveoli a special diverticulum of the lumen passes to each crescent of Gianuzzi, and ramifies within this between and perhaps partly within its component cells (figs. 29, 30).

The larger ducts acquire a coating of fibrous and elastic tissue outside the basement membrane, and, except in those of the sublingual gland, a few plain

Fig. 30.—Terminal nerve-fibrils in an alveolus of the submaxillary gland of the dog. (G. Retzius.) Chromate of silver method.

The extension of the lumen into the crescents of Gianuzzi is also shown.

muscular fibre-cells are also to be found. The columnar epithelium is here double, a second row consisting of somewhat smaller cells lying outside, and fitting between, the elongated cells which are continuous with those of the smaller ducts.

Vessels and nerves.—The **blood-vessels** of the salivary glands are numerous, and form a close capillary network outside the basement membrane both of the alveoli and the ducts.

The **lymphatics** commence in the form of lacunar clefts between and around the alveoli, lying closer to these than do the networks of blood-capillaries (Gianuzzi). The issuing lymphatics accompany the blood-vessels and ducts.

The **nerves** are large and numerous, and many of them exhibit minute ganglia, especially those in the dog's submaxillary. There are fewer in the human submaxillary gland, and no ganglia in the parotid (Klein). Some of them have been observed to end in Pacinian corpuscles of a simple kind (Krause). Many, no doubt, supply the blood-vessels, which they are known to influence. Most of them, however, appear to end in the secreting alveoli. These they reach for the most part as non-

medullated fibres, and, after piercing the basement membrane, end in an open arborescence of the finest varicose fibrils, ramifying between and around the cells of the alveoli (fig. 30).

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THE TEETH.

In the human subject as in the great majority of mammals the dentition is *diphyodont*, that is two sets of teeth make their appearance in the course of life, of which the first comprehends the *temporary* or *milk teeth*, while the second is the *permanent* set.[1] The temporary teeth are twenty in number, ten in each jaw, and the permanent set consists of thirty-two, sixteen above and sixteen below.

The human dentition is also *heterodont* ; the teeth, instead of all having the same form (*homodont* condition), differ considerably in their size, shape, and function. The twenty temporary teeth consist of four incisors, two canines, and four multicuspids or molars above and below. The thirty-two permanent teeth are four incisors, two canines, four bicuspids or premolars, and six molars in each jaw. There are no bicuspids among the temporary teeth, the eight deciduous molars preceding eight bicuspids of the permanent set. The relative position and arrangement of the different kinds of teeth may be expressed by the following formulæ, which also exhibit the relation between the two sets in these respects :—

		MO.	CA.	IN.	IN.	CA.	MO.			
Temporary teeth	Upper	2	1	2	2	1	2	=	10	= 20
	Lower	2	1	2	2	1	2	=	10	

		MO.	BI.	CA.	IN.	IN.	CA.	BI.	MO.			
Permanent teeth	Upper	3	2	1	2	2	1	2	3	=	16	= 32
	Lower	3	2	1	2	2	1	2	3	=	16	

Or they may be written more simply thus :—

$$\text{Milk teeth} \begin{cases} 2 \,.\, 1 \,.\, 2 \\ \overline{2 \,.\, 1 \,.\, 2} \end{cases}$$

$$\text{Permanent teeth} \begin{cases} 2 \,.\, 1 \,.\, 2 \,.\, 3 \\ \overline{2 \,.\, 1 \,.\, 2 \,.\, 3} \end{cases}$$

As the typical mammalian dentition is In_3, C_1, Pm_4, and Mo_3 on each side of each jaw, it follows that three pairs on each side are suppressed in man. Not unfrequently one or more of these normally suppressed teeth appear, sometimes in a well developed condition, but much more frequently they are rudimentary. From the position these supernumerary teeth occupy it is probable that the missing teeth are the second incisor and the first and fourth premolars (A. Wilson).

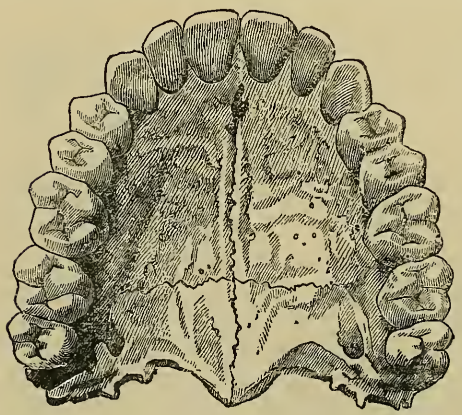


Fig. 31.—Lower aspect of superior dental arch and hard palate. (Mühlreiter.)

The curve occupied by the teeth of the upper jaw is elliptical, and of the lower parabolic. It is not broken by any interval or diastema as is the case in most mammals. The span of the upper dental arch is rather larger than that of the lower one, so that the teeth of the upper jaw slightly overlap those of the lower, both in front and at the sides. While there is a slight diminution in the height of the crowns of the teeth from the incisors backwards to the wisdom-teeth, there is in man

[1] The three permanent molars are by some regarded as belonging to the *first* dentition, since they do not take the place of any of the milk teeth, but are formed independently in a backward extension of the dental germ.

no abrupt change of level along the range. In consequence of the large proportionate breadth of the upper central incisors, the other teeth of the upper jaw are thrown somewhat outwards, so that in closure of the jaws the canines and bicuspids come into contact partly with the corresponding lower teeth, and partly

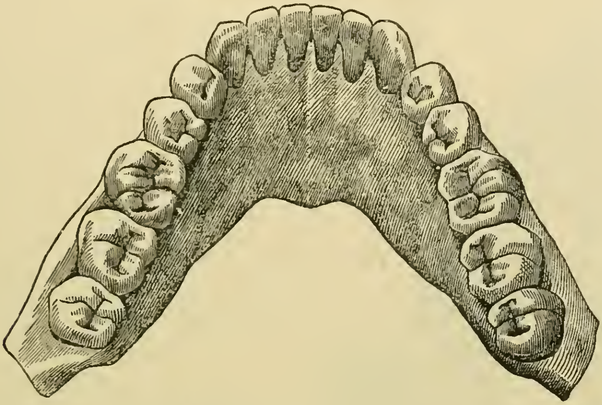
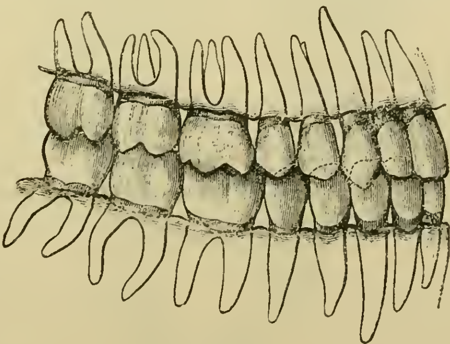


Fig. 2.—UPPER ASPECT OF LOWER DENTAL ARCH AND BODY OF LOWER JAW. (Mühlreiter.)

with those next following; and in the case of the molars, each cusp of the upper lies behind the corresponding cusp of the lower teeth. Since, however, the upper

Fig. 33.—LABIAL ASPECT OF THE RIGHT HALF OF THE TWO DENTAL ARCHES TO SHOW THE RELATION BETWEEN THE UPPER AND LOWER TEETH. (Zuckerkandl.)



molars and especially the wisdom-teeth are smaller than those below, the dental ranges terminate behind nearly at the same point in both jaws (see figs. 33 and 34).

In Europeans the upper incisors project in front of the lower incisors, but it has been shown by Turner that in some, at least, of the Australian aborigines this is not the case, the cutting edges of the lower incisors projecting as far forwards as those of the upper.

It is well known that the teeth of certain races are larger in relation to the general stature of the individual than in others. Flower has investigated this question so far as the premolars and molars are concerned. He has constructed a *dental index* by comparing the distance between the anterior surface of the first premolar and the posterior surface of the wisdom-tooth with the *basio-nasal* length of the skull. He divides the various races

Fig. 34.—LINGUAL ASPECT OF THE LEFT HALF OF THE TWO DENTAL ARCHES. (Zuckerkandl.)

according to their dental index into *microdont*, *mesodont*, and *megadont*. The microdont section contains the white races, the mesodont the Mongolian or yellow races, and the megadont the black races, including the Australians.

In consequence of the curve of the dental arch, such terms as anterior, posterior, internal and external, when used in the description of the surfaces of the

teeth, are liable to lead to confusion, to obviate which special names must be employed. The surface of a tooth directed towards the lips or cheek is therefore called labial or buccal, and that towards the tongue the lingual, while the terms proximal and distal are used to represent the surfaces that would look towards and

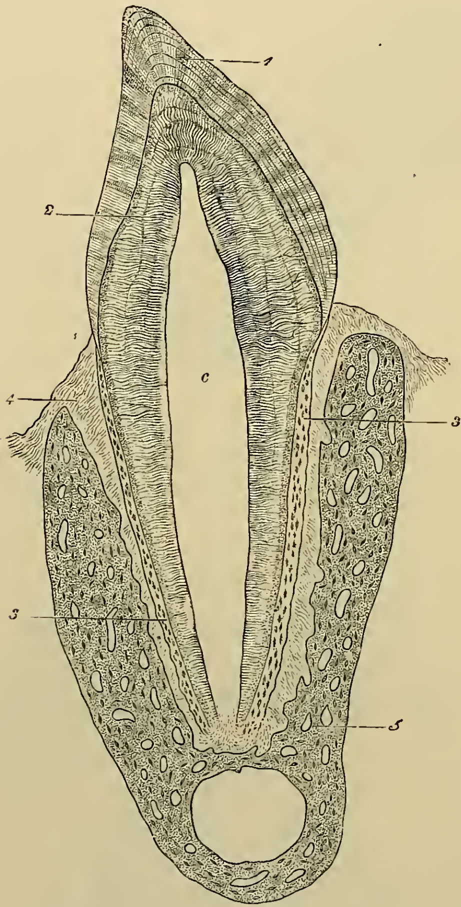


Fig. 35.—Vertical section of premolar of cat. 15 diameters. (Waldeyer.)

c, is placed in the pulp-cavity, opposite the cervix or neck of the tooth; the part above is the crown, that below is the root (fang). 1, enamel with radial and concentric markings; 2, dentine with tubules and incremental lines; 3, cement or crusta petrosa, with bone corpuscles; 4, dental periosteum; 5, bone of lower jaw.

away from the median plane were the teeth arranged in a straight line passing outwards from the mesial incisor.

A **tooth** consists of three portions, viz., one which projects above the gums and is named the *body* or *crown*, another fixed in the alveolus or socket, the *root*, consisting of a *fang* or *fangs*—and a third, intermediate between the other two, and, from being more or less constricted, named the *neck*. The size and form of each of these parts vary in the different kinds of teeth.

The roots of the teeth are accurately fitted to the alveoli of the jaws, in which they are implanted. Each alveolus is lined by periosteum (*dental periosteum*, fig. 35, *4*), which also invests the contained tooth as high as the neck, and is blended above with the dense tissue of the gums. The fangs of all the teeth taper from the cervix to the point, and this form together with their accurate adjustment to the alveolus has the effect of distributing the pressure during use over the whole socket, and of preventing it from unduly bearing on the point of the fang, through which the blood-vessels and nerves enter.

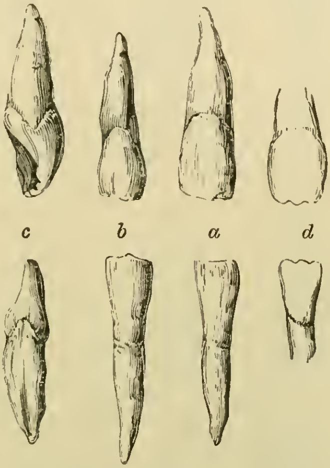
SPECIAL CHARACTERS OF THE TEETH.

The Permanent Teeth.—The **incisors** (fig. 36), eight in number, are the four front teeth in each jaw, and are so named from being adapted for cutting or dividing the food. Their *crowns* are chisel-shaped (*c*), and have a sharp horizontal cutting edge, which by continued use is bevelled off behind in the upper teeth, but in the lower ones is worn down in front, where it comes into contact with the overlapping edges of the upper teeth. Before being subjected to wear the horizontal edge of each incisor is marked by three small prominent points, separated by two slight notches (fig. 36, *d*). The labial surface of the crown is slightly convex, both from above downwards, and from side to side. The lingual surface is concave,

especially from above downwards, and presents a prominence termed the *basal ridge* or *cingulum*. The proximal and distal surfaces are triangular with the base at the gum, and the apex towards the cutting edge. The fang is long, single, conical and compressed at the sides, where it sometimes, though rarely, presents a slight longitudinal furrow (as in *c*). The lower incisor teeth are placed vertically in the jaw, but the corresponding upper teeth are directed obliquely forwards. The upper incisors are, on the whole, larger than the lower ones. Of those in the upper jaw the mesial incisors are the larger ; but in the lower jaw the mesial incisors are the smaller, and are, indeed, the smallest of all the incisor teeth. The cingulum is

Fig. 36.—Incisor teeth of the upper and lower jaws.

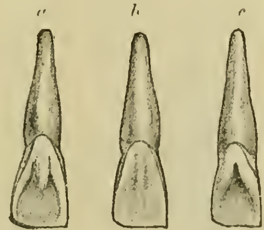
a, front view of the upper and lower mesial incisors ; *b*, front view of the upper and lower lateral incisors ; *c*, lateral view of the upper and lower mesial incisors, showing the chisel shape of the crown ; a groove is seen marking slightly the fang of the lower tooth ; *d*, the upper and lower mesial incisor teeth before they have been worn, showing the three points on the cutting edge.



absent in the lower incisors, but sometimes in the upper lateral incisors, and less frequently in the upper mesial incisors, it is developed into a distinct lingual cusp (fig. 37).

The **canine** teeth (fig. 38), four in number, are placed one on each side, above and below, next to the lateral incisors. They are larger and stronger than the incisor teeth. The *crown* is thick and conical, its labial surface decidedly convex, and the lingual concave. It may be compared to that of a large incisor tooth the angles of which have been removed, so as to leave a single central point or *cusp*, whence the name *cuspidate* applied to these teeth. The point always becomes worn down by use. The *fang* of the canine teeth is single, conical, and compressed at the sides : it is longer than the fangs of

Fig. 37.—*a*, *b*, *c*, lingual surface of upper incisor teeth showing variations in form ; in *a* the cingulum is well marked. (Zuckerkandl.)

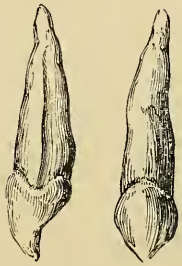


any of the other teeth, and is so thick as to cause a prominence of the alveolar arch.

The upper canines, popularly called the *eye-teeth*, are larger than the lower, and in consequence of this, as well as of the greater width of the upper range of incisors, they are thrown a little farther outwards than the lower ones. On the lingual surface of the upper canine a well-marked ridge passes from the apex of the cusp to the cingulum, where there is frequently a distinct tubercle. The lower canine has neither a lingual ridge nor cingulum. The *root* of the upper canine is almost invariably single, while that of the lower is often bifid at its apex. In the dog-tribe, and in the carnivora generally, these teeth acquire a great size, and are fitted for seizing and killing prey, and for gnawing and tearing it when taken as food.

The **bicuspids** (fig. 39), also called *premolars*, are four in each jaw ; they are shorter and smaller than the canines, next to which they are placed. The crown is compressed proximo-distally, and both its labial and lingual surfaces are convex The grinding surface shews two cusps—a large labial and a smaller lingual—

separated by a deep fissure. The fang is compressed in the same direction as the crown, and is grooved on its proximal and distal surfaces so as to



b a

Fig. 38.—Canine tooth of the upper jaw.

a, front view ; *b*, lateral view, showing the long fang grooved on the side.

shew a tendency to be divided into a labial and a lingual portion.

The upper bicuspids differ very considerably from the lower, and while in the latter there is a decided distinction between the first and second, in the case of the two upper bicuspids there is but little difference. The labial surface of the crown of the first upper bicuspid has a vertical ridge passing from its apex upwards towards the neck ; this ridge is bounded by two lateral depressions (see *a*, fig. 39). The lingual surface of the crown is smaller and more convex both longitudinally and transversely than the labial aspect. It

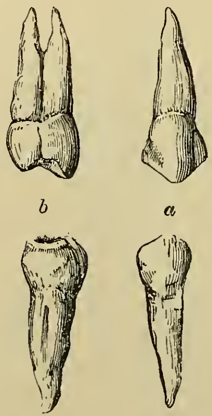


Fig. 39.—First bicuspid tooth of the upper and lower jaws.

a, labial view ; *b*, lateral view, showing the lateral groove of the fang, and the tendency in the upper to division.

has usually two roots, a labial and a lingual ; sometimes only one, and more rarely three, two labial and one lingual. In the second upper bicuspids the labial and lingual surfaces are nearly equal, and the labial ridge is indistinct, while the fang is more frequently single than in the first bicuspid. The lower bicuspids are smaller than the upper ones, their cusps are less deeply divided, and the lingual surface is much less convex than the labial. In the upper bicuspids the two cusps are separated by a deep fissure, while in the lower they are united by a low ridge. The lower bicuspids have generally single roots, but occasionally the root is divided into a labial and a lingual fang. The first lower bicuspid has sometimes only one cusp distinctly marked, viz. the labial, and in that case it approaches in figure to a canine tooth. The second bicuspid is larger

Fig 40.—First molar tooth of the upper and lower jaws.

They are viewed from the buccal aspect.

than the first, and its lingual cusp is nearly as prominent as the labial one, whereas in the first bicuspid the lingual cusp is much smaller.

The **molar** teeth (fig. 40), true or large molars, or *grinders*, are twelve in number, and are arranged behind the bicuspid teeth, three on each side, above and below. They are distinguished by the large size of the crown, and by the great width of its grinding surface. The first molar is the largest, and the third is the smallest, in each range, so as to produce a gradation of size in these teeth. The last of the range, owing to its late appearance through the gum, is called the *wisdom-tooth.* The *crowns* of the molar teeth are low and cuboid in their general form. Their labial and lingual surfaces are convex, but the proximal and distal surfaces are flattened. The grinding surface is nearly square in the lower teeth, and rhomboidal in the upper. the corners being rounded off ; it bears four or five trihedral tubercles or

cusps (whence the name *multicuspidati*), separated from each other by a crucial depression.

The crown of the first upper molar bears four cusps, situated at the angles of the masticating surface; of these the proximo-lingual is the largest, and is usually connected with the labio-distal cusp by a low oblique ridge. This tooth has occasionally a fifth cusp situated on the lingual side of the proximo-lingual cusp;

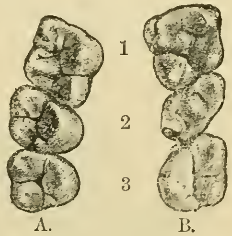


Fig. 41.—Grinding surface of the upper molars. (Zuckerkandl.)

A, on right side; the first molar has four cusps, and the second and third three each.

B, another set from the left side, with the same number of cusps as in A, except that a small additional cusp is seen on the lingual side of the proximo-lingual cusp of the first molar. The third molar is larger than the second.

this additional cusp is small, and rarely, if ever, reaches the grinding surface. The second upper molar is generally described as having four cusps, but according to Zuckerkandl and Röse there are often only three. Zuckerkandl found four cusps in 45·6 per cent. of Europeans, the cusps being reduced to three in 54·4 per cent., while in the lower races four cusps were found in 73·5 per cent. Röse's results agree essentially with those of Zuckerkandl. In the upper wisdom-tooth the two lingual cusps are usually blended. The crowns of the lower molars, which are larger than those of the upper, have five cusps, the additional one being placed between the two distal ones, and

Fig. 42.—Grinding surface of the lower molars on left side. (Zuckerkandl.)

In this series the first molar has five cusps, the second 4, and the third 4, and the teeth diminish in size from the first to the third.

rather to the outer side. Not unfrequently the second molar has only four cusps, but this reduction in the number of cusps rarely affects the first and third molars. The third molar is usually as large as and sometimes even larger than the second. The *fangs* of the molar teeth are multiple. In the first and second molars of the upper jaw the fangs are three in number, viz. two labial and one lingual; the labial fangs are short, divergent, and directed towards the antrum of the superior maxilla, while the lingual fang is larger and longer and directed towards the palate, its distal border extending as far back as the labio-distal fang. The first and second molars of the lower jaw have each two broad compressed fangs, one proximal and the other distal; they are grooved on the faces that are turned towards each other as if each consisted of two fangs fused together. In the wisdom-teeth of both jaws the fangs are often collected into a single irregular, conical mass, which is either directed backwards in the substance of the jaw, or curved irregularly; this composite fang sometimes shows traces of subdivision, and there are occasionally two fangs in the lower teeth and three in the upper.

Homologies of the teeth.—Two main views are held as to the phylogeny of the multicuspidate teeth of various mammals, such as the molars in man. According to Röse and others these teeth are formed by the fusion of a number of originally simple cones, such as are found in the Reptilia. The evidence offered in support of this view is mainly embryological. On the other hand, Cope and Osborn, from a study of the teeth in a large series of fossil mammals, hold that the primitive form of mammalian molar was a single cone, to which all the other cusps have been successively added.

In fishes, amphibia, and reptilia, in place of two series of teeth such as occur in mammals, there is throughout life a constant succession of series which replace one another from behind forwards. There can be little doubt that the two series, milk and permanent, of mammals represent a part, at least, of the successive series of reptilian teeth. Some considerable amount

of discussion has of late years taken place as to which of the two dentitions is the primary, for although in higher mammals the milk dentition is the first to appear, in marsupials it appears to be absent; and it has hence been inferred that it is really only of secondary development. The most recent researches seem, however, to show that the milk dentition is represented in a rudimentary form even in marsupials, and it would further appear that in exceptional instances in higher mammals, and in man, a third, and even a fourth, series of teeth may be produced in connection with persistent remains of the dental lamina, behind and lateral to the permanent teeth; this being an apparent reversion to the reptilian conditions of dental succession. For a full discussion of these and other points in connection with the homologies of the teeth, see Schwalbe, "Ueber Theorien der Dentition," Verhandl. d. anat. Gesellschaft, Anat. Anzeiger, 1894.

THE MILK-TEETH (fig. 43).—The temporary or milk-teeth are distinguished from the permanent by the marked bulging of the crown close to the neck, so that

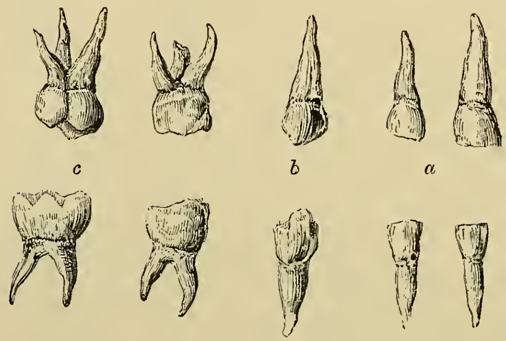


Fig. 43.—MILK TEETH OF THE RIGHT SIDE OF THE UPPER AND LOWER JAWS.

a, the incisors; *b*, the canines; *c*, the molar teeth.

the latter shews a well-marked constriction. The temporary incisors and canine teeth resemble those of the permanent set in their general form, but they are of smaller dimensions, and all their characteristic markings are much less decided, especially those in the canines.

The temporary molars are larger than the bicuspids which succeed them. The hinder of the two is much the larger, being, indeed, the largest of all the milk-teeth. The first upper milk molar has only three cusps, two labial and one lingual; the second has four. The first lower temporary molar has four cusps, and the second five, of which in the latter case three are labial. The fangs of the temporary molars resemble those of the permanent set, but they are smaller and are more divergent from the neck of the tooth.

STRUCTURE OF THE TEETH.

On making a section of a tooth, it is found to be hollow within (fig. 44). The form of the cavity bears a general resemblance to that of the tooth itself; it occupies

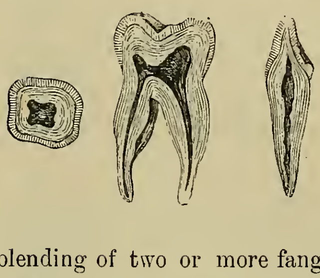


Fig. 44.—SECTIONS OF AN INCISOR AND MOLAR TOOTH.

the interior of the crown, and extends along each fang, at the point of which it opens by a small orifice. In the incisor teeth the cavity is prolonged above into two tapering canals, which proceed one to each corner of the crown; in the bicuspid and molar teeth it advances a short distance into each cusp. In the case of a root formed by the blending of two or more fangs, each division has a separate canal prolonged to its apex.

Pulp of the teeth.—The central cavity of a tooth is called the *pulp-cavity*, because it is occupied by a soft, highly vascular, and sensitive substance, called the *dental pulp*. This pulp (fig. 45, *F*) consists of jelly-like connective tissue containing cells, blood-vessels and nerves, and fine fibres. The fibres appear to be formed from processes of the cells: according to Röse they are not collagenous, although a few

bundles of ordinary collagenous connective tissue fibres may accompany the blood-vessels and nerves. The cells are partly disseminated in the matrix, and partly form a stratum at the surface of the pulp, where, during the formation of dentine, they are elongated, somewhat like the cells of columnar epithelium (see fig. 65, *c*, p. 44), but after the dentine is completely formed they become flattened like the osteoblasts under the periosteum of bone. These superficial cells (*odontoblasts*, fig. 45, *Od*, *Od*[1]) send processes into tubules in the dentine, to be afterwards noticed, of which more than one may come from the same cell. The filaments within the tubules were first noticed by J. Tomes, and are known as Tomes' fibres. The arteries and nerves, which are derived from the internal maxillary and fifth pair respectively enter by

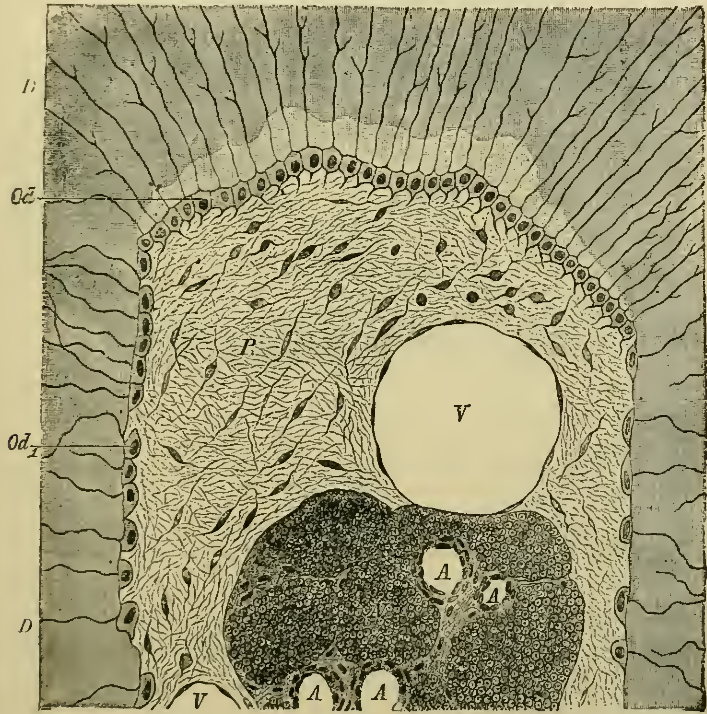


Fig. 45.—Section across the root of a young tooth showing its pulp *in situ*. (Röse.) $\frac{250}{1}$.

P, pulp; *V*, *V*, veins; *A*, *A*, arteries; *N*, nerve-bundles; *Od*, columnar odontoblasts still depositing dentine; Od_1, flattened odontoblasts, which have ceased to form dentine.

the aperture at the point of each fang. The vessels form a capillary network beneath the superficial cells; the nerves end in fine non-medullated fibrils, which are distributed abundantly at the surface of the pulp and run up between the superficial cells, but they have not been traced into the dentinal tubules.

Weil has described a clear layer (*basal layer*) under the odontoblasts, pervaded with fibres, which he regards as derived from the odontoblasts. It is, however, somewhat uncertain whether the layer described is not an artefact, due to the shrinking of the main mass of the pulp from the layer of odontoblasts. It is only seen in the crown of the teeth. No lymphatics have been seen in the pulp.

Hard tissues of the teeth.—The hard part of a tooth is composed of three distinct substances,—viz., the proper dental substance, *ivory* or *dentine*, the *enamel*,

and the *cement* or *crusta petrosa.* The dentine constitutes by far the larger portion : the enamel is found only upon the exposed part or crown ; and the cement covers with a thin layer the surface of the fang.

The **dentine** (Owen) resembles bone in its general aspect and chemical constitution, but is not identical with it in structure.

The dentine of human teeth is composed of 28 parts per cent. of animal. and 72 of earthy matter. The former is resolved into gelatin by boiling. The composition of the latter.

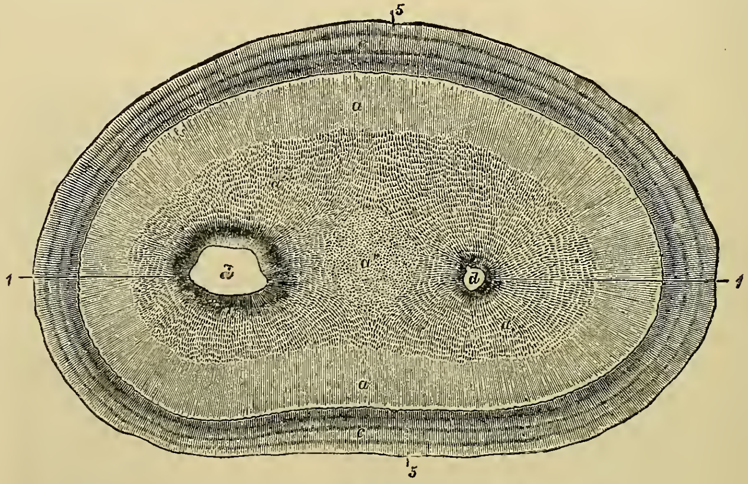


Fig. 46.—Section of a tooth across the crown. (Rauber.) $\frac{9}{1}$

a, dentine, the tubules cut longitudinally ; *a'*, the same cut obliquely ; *a''*, the same cut across ; *c*, enamel, showing contour lines (5) ; *d*, *d*, portions of the pulp cavity extending into the cusps, with the dentinal tubes converging horizontally towards them (1).

according to Bibra, is as follows, viz., phosphate of lime 66·7 per cent., carbonate of lime 3·3, phosphate of magnesia and other salts, including a trace of fluoride of calcium, 1·8. Berzelius found 5·3 carbonate of lime.

The dentine is penetrated throughout by fine tubes (*dentinal tubes*), which being nearly parallel, give it a striated aspect (figs. 46, 47). When a thin section of a macerated tooth, prepared by grinding, is viewed under the microscope by transmitted light, the solid substance, or matrix, is transparent and apparently homogeneous, while the tubes, being (in a dried specimen) filled with air, are dark ; but when seen with reflected light on a dark ground, the latter appear white ; in these respects they resemble lacunæ and canaliculi of bone.

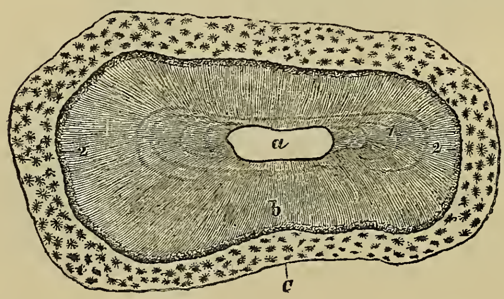


Fig. 47.—Section of the same tooth across the fang. (Rauber.) $\frac{9}{1}$

a, pulp cavity ; *b*, dentine ; *c*, cement ; 1, incremental lines ; 2, granular layer.

The *dentinal tubules* open at their inner ends into the pulp-cavity, which has accordingly very numerous minute orifices over the whole surface. Thence they pass in a radiated manner through every part of the ivory towards its periphery. In the upper part of the crown they have a vertical direction ; but towards the sides, and in the neck and root, they become gradually oblique, then horizontal, and

are finally even inclined downwards towards the point of the fang. The tubules describe in their course two or three gentle curves (*primary* curvatures, fig. 35), and each is besides twisted throughout its whole length into numerous fine spiral turns, which follow more closely one upon another; these are the *secondary* curvatures (fig. 48). In form a tubule may accordingly be likened to the thread of a corkscrew, stretched so that the turns are drawn far apart, and their breadth proportionally diminished (Welcker).

The tubes are only slightly divergent as they pass towards the surface; and, as they occasionally divide dichotomously, and at first without being much diminished in size, they continue to occupy the substance of the dentine at almost equal distances, and their nearly parallel primary curvatures produce, by the manner in which they reflect the light, an appearance of concentric undulations in the dentine,

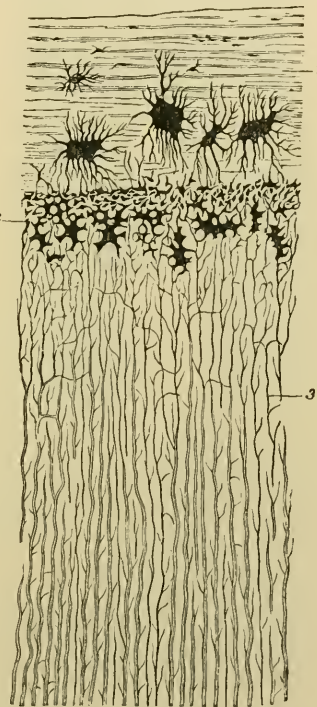


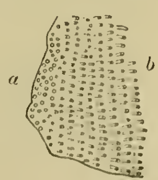
Fig. 48.—Section of fang, parallel to the dentinal tubules (human canine). Magnified 300 diameters. (Waldeyer.)

1, cement, with large bone lacunæ and indications of lamellæ; 2, granular layer of Purkinje (interglobular spaces); 3, dentinal tubules.

which may be well seen with a low magnifying power (*Schreger's lines*). The average diameter of the tubules at their inner and larger end is 0·0055 mm., and the distance between adjacent tubules is commonly about two or three times their width. From their sides, numerous immeasurably fine branches are given off, which penetrate the hard intertubular substance, where they either anastomose or terminate blindly. These lateral ramuscules are more abundant in the fang. Near the periphery of the ivory the tubules, which by division and subdivision have become very fine, terminate imperceptibly by free ends.

The tubules have each a proper wall (*dentinal sheath* of Neumann) independent of the intertubular matrix, but intimately adhering to it. By steeping sections of decalcified dentine in strong hydrochloric acid, the matrix is destroyed, and the membranous tubes, which consist of a more resisting material (probably elastic substance), remain behind. Röse states that these sheaths, which are formed of dentinal matrix which calcifies either late or

Fig. 49.—Sections of dentinal tubules. (After Fraenkel.)
a, cut across; *b*, cut obliquely. (About 300 diameters.)



not at all, anastomose freely, and that it is their anastomoses which have been often taken for that of the tubules themselves.

In the temporary, and sometimes even in the permanent teeth, the tubules are constricted at short intervals, so as to present a moniliform character. The terminal branches of tubules are occasionally seen to pass on into the cement which covers the fang, and to communicate with canaliculi proceeding from the characteristic lacunæ found in that osseous layer. Tubules have likewise been observed by Tomes and others passing into the enamel in the teeth of marsupial animals, and in a less marked degree,

in human teeth. In this case they pass, not into the enamel prisms, but into the inter-prismatic substance.

The *intertubular substance* is translucent. The animal matter which remains after the earth has been removed by an acid, may be torn into laminæ (Sharpey),

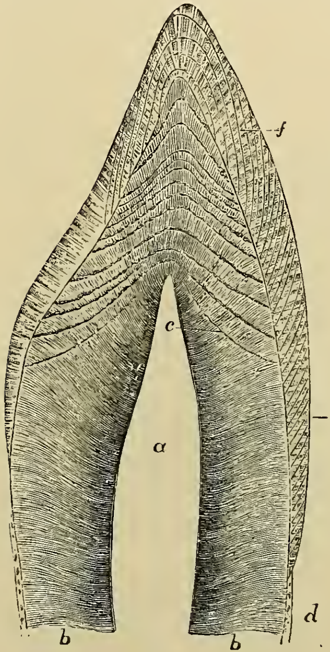


Fig. 50.—Vertical section of the upper part of an incisor tooth. (From Kölliker.) Magnified 7 diameters.

a, the pulp-cavity; *b*, dentine; *c*, arched incremental lines; *d*, cement; *e*, enamel, with bands indicating the direction of the ranges of fibres; *f*, coloured lines of the enamel.

parallel with the internal surface of the pulp-cavity, and therefore across the direction of the tubules. It has been shown by Ebner and Mummery that the matrix contains fine fibrils like those of the matrix of bone. These fibrils are not themselves calcified but are enveloped in the calcified inter-fibrillar substance, and, according to Mummery, are continuous with fibrils of the dental pulp.

The laminated structure is an indication of the deposition of dentinal substance in successive strata in the process of formation of the tooth—the laminæ corresponding with the shape of the pulp-surface at successive stages of the process. Not unfrequently lines, varying in number and breadth, are seen in sections of the dry tooth, conforming in direction with the lamination just spoken of (*incremental lines*, Salter, fig. 50, *c*). They are caused by the drying of imperfectly calcified dentine, which shows little cavities bounded by, and therefore receiving their figure from, minute nodules or globules of dentine, and hence named *interglobular spaces* (fig. 51, *c*). The interglobular spaces, and the globules surrounding them, vary in size

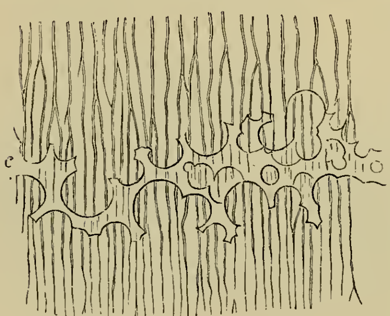


Fig. 51.—A small portion of the dentine with interglobular spaces. (From Kölliker.) 350 diameters.

c, portion of incremental line formed by the interglobular spaces, which are here filled up by the transparent material used in mounting the specimen.

within wide limits. A layer, in which they are very fine—*granular layer* (fig. 48, 2)—is not uncommonly found towards the outer surface of the dentine.

The **enamel** is that hard white covering which encrusts and protects the exposed portion or crown of a tooth. It is the hardest of all the dental tissues, but is gradually worn down by protracted use. It is thickest on the grinding surface and cutting edge of the teeth, and becomes gradually thinner towards the neck, where it ceases.

According to Bibra, it contains of earthy constituents 96·5 per cent., viz., phosphate of lime with traces of fluoride of calcium 89·8, carbonate of lime 4·4, phosphate of magnesia and other salts 1·3, and of animal matter only 3·5 per cent. Berzelius, however, gave the proportion of carbonate of lime as 8, and of animal matter as only 2 per cent.

The enamel is made up entirely of very hard and dense microscopic columns or prisms, arranged closely together, side by side, and set by one extremity upon the

Fig. 52.—SECTION OF PART OF THE CROWN OF A TOOTH, PARALLEL WITH THE GENERAL SET OF THE ENAMEL PRISMS. (Rauber.) $\frac{200}{1}$

a, pointed projection of dentine ; *b*, tubules extending from the dentine into the enamel ; *c*, enamel prisms ; *d*, prisms cut across ; *e*, cuticle of the enamel.

subjacent surface of the dentine (fig. 52). The columns are disposed in ranges, which, on the grinding surface, are set vertically, but on the sides of the crown get more horizontal. Near the dentine the prisms cross one another in the alternate ranges, but become parallel as they approach the surface of the tooth. An effect of radial alternate light and dark stripes is obtained (as in fig. 50) (A. Retzius). A series of concentric lines is likewise to be seen crossing the enamel fibres : these are termed *coloured lines* from their brown appearance. According to Ebner, these are produced by some of the inter-prismatic spaces becoming in the dried tooth filled with air. Minute fissures not unfrequently exist in the deep part of the enamel, which run between clusters of the prisms down to the surface of the dentine (fig. 53, *c*) ; and other much larger and more evident fissures

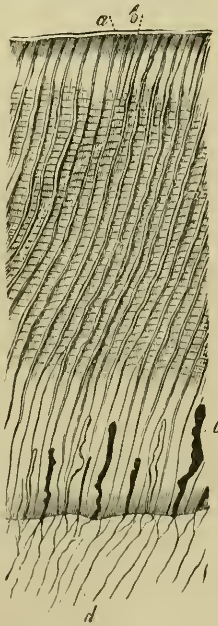


Fig. 53.—THIN SECTION OF THE ENAMEL AND A PART OF THE DENTINE. (From Kölliker.) 350 DIAMETERS.

a, cuticle of the enamel ; *b*, enamel-fibres or columns with fissures between them and cross striæ ; *c*, clefts in the enamel communicating with the extremities of some of the dentinal tubules (*d*).

are often observed leading down from the depressions or crevices between the cusps of the molar and premolar teeth. The unworn surface of the enamel is finely striated.

The *enamel-columns* (fig. 52) have the form of solid six-sided prisms. Their diameter is ordinarily about 0·005 mm. They are marked by frequent dark transverse shadings, which are usually ascribed to the existence of shallow constrictions along the fibres. Although this may be in part the cause, it is not improbable that the transverse markings are largely the result of the manner in which the prisms are built up in successive stages by the cells which produce them, each marking representing the termination of a stage. The inner ends of the prisms are implanted in minute hexagonal depressions on the surface of the dentine ; whilst the outer ends are free, and present, when examined with a high magnifying power, a tesselated appearance (fig. 54, B). The prisms are united by a small amount of a substance which appears similar to the intercellular substance of an epithelium, but is perhaps calcified. In marsupials and some rodents there are regular canaliculi in this interprismatic substance.

When submitted to the action of dilute acids, the enamel is almost entirely dissolved, and leaves scarcely any discernible traces of animal matter. The centre

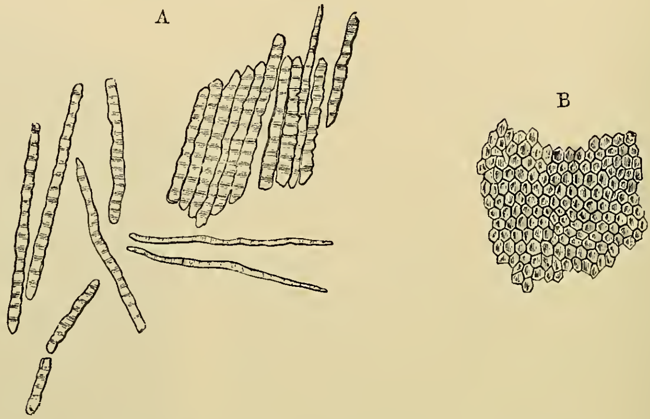


Fig. 54.—Enamel-prisms. (From Kölliker.) 350 diameters.

A, fragments and single columns of the enamel, isolated by the action of hydrochloric acid. B, surface of a small fragment of enamel, showing the hexagonal ends of the prisms.

of the prisms is first dissolved, showing this part to be less firmly calcified than the periphery. After exposure for a short time to the action of an acid, the enamel of

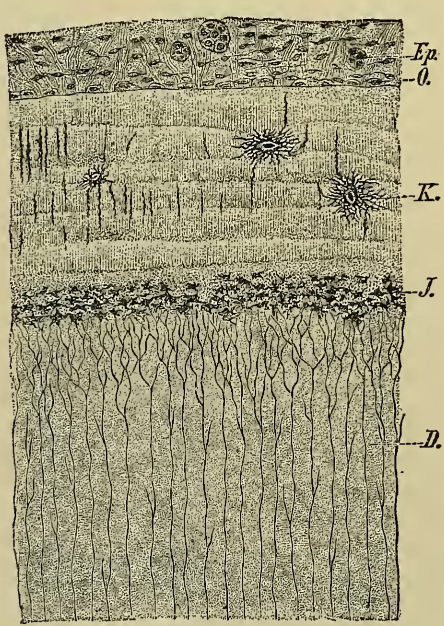


Fig. 55.—Section of the fang of a tooth showing dentine and cement together with the dental periosteum. (Röse.) $\frac{200}{1}$.

Ep., nests of epithelial cells within the dental periosteum which are the remains of the epithelial sheath of Hertwig ; *O.*, osteoblasts which have formed the cement ; *K.*, lacuna of the cement ; *J.*, granular layer of the dentine ; *D*, dentine.

newly formed or still growing teeth may be broken up, and its structural elements more easily distinguished. In broken enamel prisms thus treated a longitudinally striated structure has been described (Annell).

It is further found, on treatment with acid, that a very thin membrane (*enamel cuticle*, *Nasmyth's membrane*) entirely covers the enamel of unworn teeth upon its outer surface (figs. 52, 53). This membrane forms a protective covering to the enamel. It is of an epithelial and horny nature, and withstands prolonged boiling as well as the action of acids and other re-agents. It is formed of short flattened prisms which are the remains of the last formed portions of the enamel prisms, and which have remained uncalcified. After the action of nitrate of silver, it exhibits markings like those seen in a pavement epithelium.

The **crusta petrosa or cement** is the third substance which enters into the formation of the teeth. This is a layer of true bone, slightly modified in structure,

and investing that part of the dentine which is not protected by the enamel. It covers the whole fang, towards the lower end of which it becomes gradually thicker, and is specially developed at the apex, and along the grooves of the compound fangs. As life advances, the cement generally grows thicker, especially near the point of the fang, where it sometimes blocks up the orifice leading to the pulp-cavity.

The crusta petrosa is lamellar in structure, and contains lacunæ and canaliculi resembling those of bone but larger and more irregular (fig. 55, *K*). Where the cement is very thick it may contain Haversian canals. On the milk teeth the cement is thinner, and contains fewer cells. Perforating and decussating fibres, similar to those of ordinary bone, occur in the cement. It is covered externally by the dental periosteum, by means of which it is firmly fixed into its bony socket.

VARIETIES OF DENTINE.

Certain varieties of hard tissue are liable to be formed in the pulp-cavity of a tooth after the regular production of the dentine is completed. The two chief kinds hitherto described are the following :—

1. **Osteodentine** (Owen).—This is a hard substance which sometimes becomes deposited within the pulp-cavity, somewhat resembling bone in structure. It is traversed by canals, which contain blood-vessels and pulp-tissue, and may be surrounded by concentric lamellæ like the Haversian canals of bone. From these canals numerous tubules radiate, larger than the canaliculi of bone, resembling, in this respect, and also in their mode of ramification, the tubes of the dentine. It may or may not coalesce with the previously formed dentine.

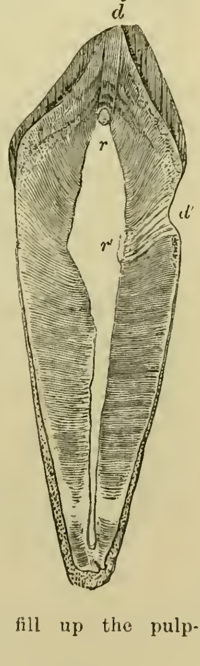


Fig. 56.—Longitudinal section of incisor tooth showing dentine of repair. Slightly magnified. (Reduced from Salter.)

d, *d′*. denuded surfaces of dentine ; *r*, *r′*, corresponding deposits of secondary dentine. Two or three incremental lines are observed in the dentine.

2. **Secondary dentine, Dentine of repair** (Salter).—When the outer surface of the dentine becomes denuded at any place, so that the peripheral ends of the tubules are there exposed, as may happen in the crown from injury or wear of the enamel, or at the cervix from continued friction and abrasion of the cement, a deposition of dentinal matter occurs on the inner surface of the dentine exactly corresponding in position and extent with the area occupied by the central ends of the exposed tubules. Many of the affected tubules become subsequently filled up by a deposit of hard matter within them, so that on section both the secondary dentine and the corresponding part of the primary dentine appear clearer and more transparent than the remainder of the dentinal substance (see fig. 56).

When the surface-injury has been considerable, the dentine of repair is largely in excess, and may in such cases completely fill up the pulp-cavity.[1]

DEVELOPMENT OF THE TEETH.[2]

The first trace of the teeth appears during the sixth week of intra-uterine life (in embryos of 11 mm. to 12 mm. long) in the form of a longitudinal thickening of the epithelium of the mouth along the line of the future jaw. The thickening in question is produced by multiplication of the deeper-lying cells of the epithelium, and in some animals, *e.g.*, ruminants, is marked by a prominence raised above the general level of the epithelial surface. A prominence is found in the human

[1] In some animals other kinds of dentine are found ; for a description of these, and other details regarding the structure and development of the teeth of vertebrates, the student is referred to the "Manual of Dental Anatomy," by C. S. Tomes, F.R.S.

[2] The following account of the development of the teeth is mainly based upon the description given by Rose.

embryo for a very short time, and at one point only of the jaw. Nevertheless it is considered by Röse of great morphological importance, as representing a

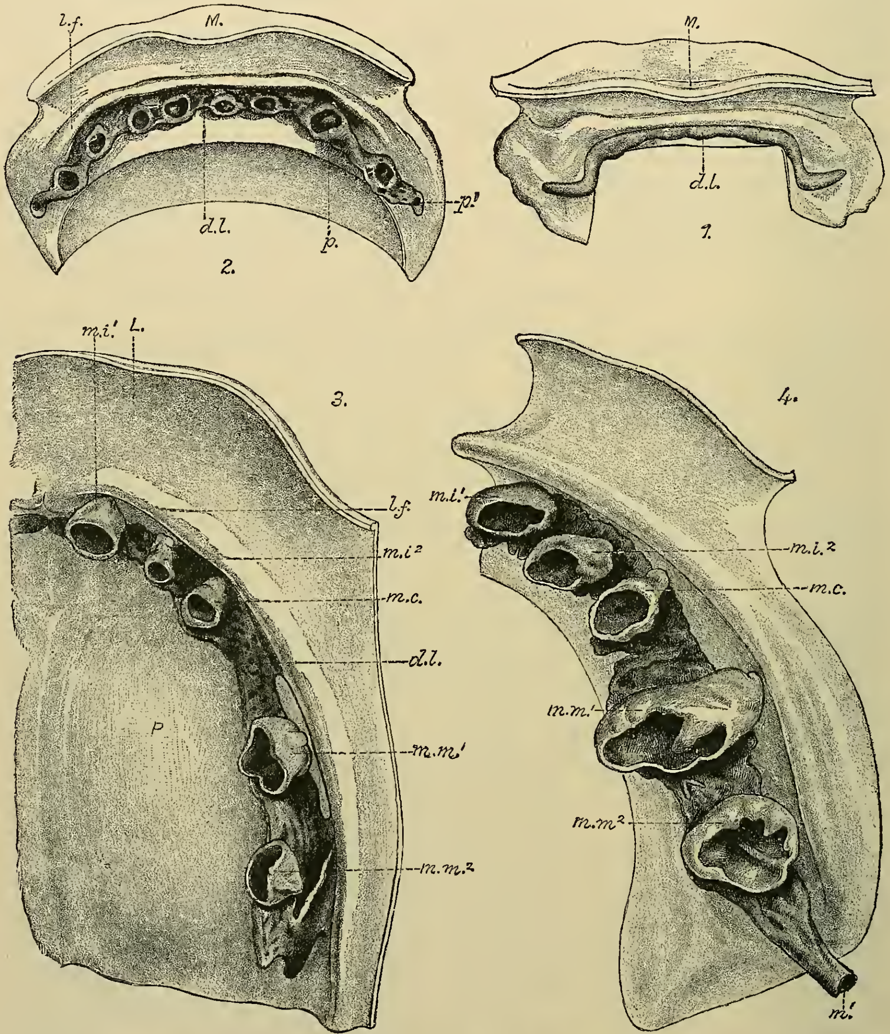


Fig. 57.—Figures (from C. Röse's models) showing four successive stages in the development of the dental lamina and tooth germs of the milk teeth of the upper jaw. Only the buccal epithelium and the epithelial structures of the tooth germs are represented, and everything is shown as seen from above.

1. From an embryo 25 mm. long.—*d.l.*, dental lamina; *M.*, aperture of mouth.
2. From an embryo 40 mm. long.—*M.*, mouth; *l.f.*, reverse of labio-dental furrow; *d.l.*, dental lamina; *p.*, mould for papilla of milk canine; p^1, mould for papilla of second milk molar.
3. From an embryo 115 mm. long.—*L.*, epithelial layer of upper lip; *l.f.*, reverse of labio-dental furrow; *d.l.*, dental lamina; $m.i.^1$, epithelial rudiment of first milk incisor; $m.i.^2$, *m.c.*, $m.m.^1$, $m.m.^2$, epithelial rudiments of second milk incisor, and of milk canine, and first and second molars respectively.
4. From an embryo 180 mm. long.—$m.i.^1$, $m.i.^2$, *m.c.*, $m.m.^1$, and $m.m.^2$, as before; $m.^1$, rudiment of first permanent molar.

vestige of the primitive larval epithelial teeth which occur in fishes and amphibians. The longitudinal epiblastic thickening grows into the mesoblast, as a strand of cells which is at first semicircular in section, and the mesoblast encloses

it in a continuous groove; for there is at first no indication of the formation of separate teeth. The strand in question has been called the "dental lamina" (Zahnleiste): it is also known as the "common enamel germ," because some of its cells are concerned in the production of the enamel of the teeth. But it is not merely a dental germ, for before long (embryo of 17 mm., or seventh week) it is found that the originally simple strand of cells is separating longitudinally into two. One of these, the outer, or labial, which dips vertically into the embryonic jaw, becomes hollowed out from the surface to form the labio-dental furrow, and may accordingly be termed the *labio-dental strand*, whilst the other, lingual or inner part, takes at first a vertical and then an inward (lingual) direction, and is the actual tract of cells in connection with which the teeth of both dentitions subsequently

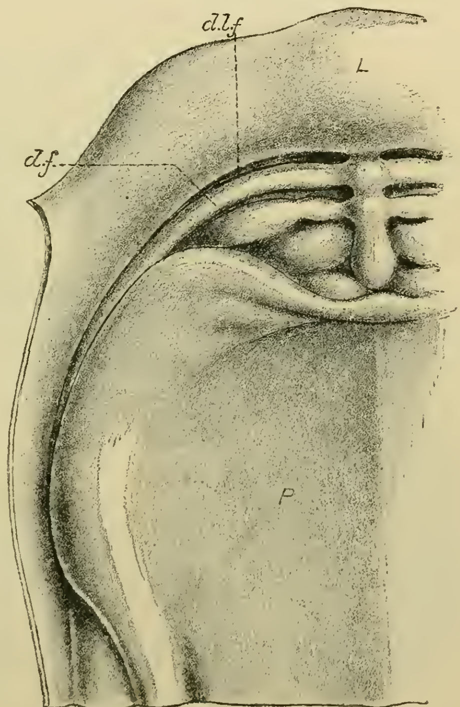


Fig. 58.—Palatine surface of the model which is shown from above in fig. 57, 3.

P, palate; *L*, upper lip; *d.l.f.*, labio-dental furrow; *d.f.*, dental furrow.

become developed. The name *dental lamina*, or *common dental germ*,[1] should therefore be retained for this portion of the original strand of epiblast cells alone. The separation of the two strands begins in front and extends gradually backwards: it is not complete until the eleventh or twelfth week. The dental lamina, when thus separated from the labio-dental strand, forms a flat band of cells (fig. 57, 1, *d.l.*) connected by one edge with the epithelium lining the mouth, whilst the other, or free edge, projects almost horizontally inwards (*i.e.*, tongue-wards) in the substance of the embryonic jaw. Subsequently, however, as the milk teeth develop, it takes a vertical direction. Over the line of its attachment to the epithelium of the mouth there is a shallow furrow, the *dental furrow* (fig. 58, *d.f.*), which is at first rather outside (or on the labial side of) the most prominent part of the jaw, but gradually comes to lie further inwards. At about nine weeks (embryo of 25 mm.) the free border of the dental lamina begins to exhibit ten enlargements in each jaw corresponding in situation to the ten milk teeth. At ten weeks (embryo of 32 mm.) these enlargements show a moulding on one of their surfaces (upper in the upper jaw and lower in the lower) (fig. 57, 2, *p.*, *p.*[1]), and the adjacent mesoblast fits against this moulded surface and becomes differentiated into the form of a papilla, which thus at once begins to have the shape of the crown of the future tooth, being simple in the incisors and multiple in the molars.[2] The papillæ have all appeared by eleven and a half weeks, and the enlargements of the dental lamina, which are now very evident, grow around

[1] "Dental germ" is used instead of the former expression "enamel germ," because the cells in question not only form enamel, but also appear to determine the formation of dentine (by the mesoblast cells in contact with them) (see p. 46).

[2] In the canines, however, the papilla is at first double, not single. It has been suggested that this is probably an indication of the originally premolar character of these teeth.

and gradually invest the papillæ at their sides also. The dentine and pulp of the milk teeth are formed from these papillæ, whilst the enlargements of the dental lamina which invest them form *special dental germs* for those teeth, to which also they furnish the enamel.

In the meantime the dental lamina has grown further inwards (tongue-wards) beyond these prominent special dental germs, which appear now as ten rounded masses of cells attached to the labial side of the flat common dental lamina "like swallows' nests built against a board" (fig. 57, 3). The common dental germ extends backwards in the substance of the jaw a short distance behind the last of these special dental germs for the milk-teeth. This backward extension of the dental lamina is not directly connected with the buccal epithelium. At about seventeen weeks (embryo of 18 centimeters long) it shows another

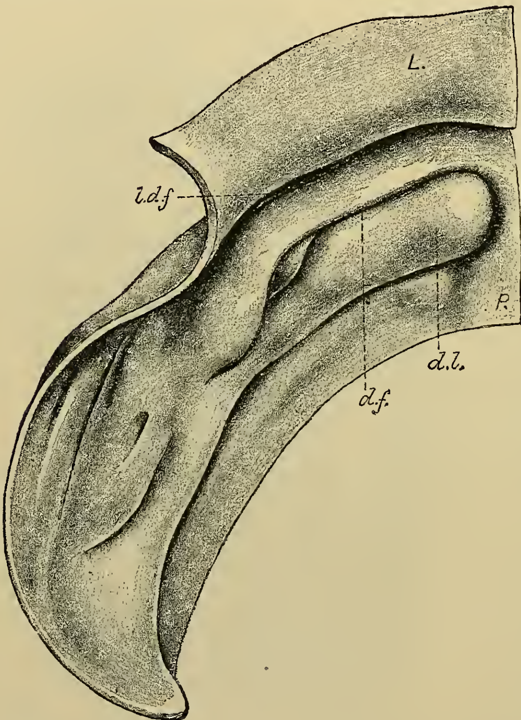


Fig. 59.—Gingival surface of the model which is shown from above in fig. 57, 4.

P., palate ; *L.*, upper lip ; *l.d.f.*, labio-dental furrow ; *d.f.*, dental furrow ; *d.l.*, prominence caused by dental lamina with its enlargements.

enlargement, which is the special germ of the first permanent molar, and, in connection with this enlargement, the corresponding papilla soon makes its appearance (fig. 57, 4, m^1). Behind this again the dental lamina is continued backwards into the gum as a thin flat band of epithelium. About four months after birth an enlargement for the second permanent molar appears, and the corresponding papilla at six months, and about the third year the enlargement for the third permanent molar, or wisdom-tooth, begins to be visible in a still further backward extension of the dental lamina, and its papilla is seen about the fifth year. Meanwhile, important changes have been occurring in the dental lamina, in the attachments of the special germs to it, and in the special germs themselves.

Changes in the dental lamina.—The changes in the common dental lamina consist in the formation of numerous apertures of irregular size and form, with the result that from a complete flat band of cells it becomes partly atrophied and changed into a cribriform tract (fig. 63), so that in transverse sections of the jaw it appears to be broken up into separate portions (fig. 64). This is, however, not the case, although the lamina is pierced with apertures so as to be almost reticular in character. This atrophic change begins in front about the seventeenth week, and gradually extends backwards, but the most posterior part is still complete (non-cribriform) at the time of birth, and even for some time after. Moreover, at certain points the reticulation is absent, viz., on the lingual side of and slightly lateral to the special germ of each milk-tooth, and at these points the dental lamina

again undergoes a thickening. These thickenings become the special enamel germs for the teeth of succession of the second dentition. In connection with each one a papilla becomes formed in the same way as for the milk teeth, but by no means

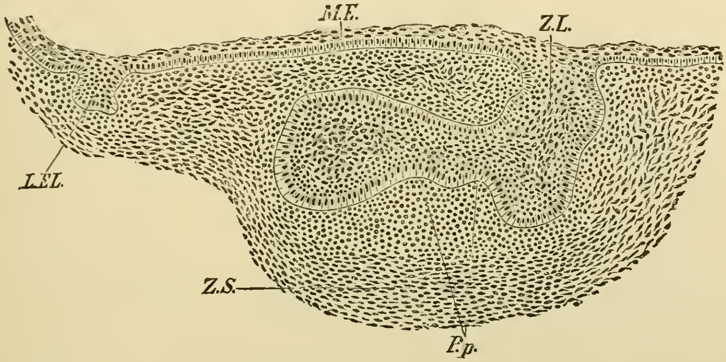


Fig. 60.—Sagittal section through the first lower milk molar of a human embryo 30 mm. long. (Röse.) $\frac{100}{1}$.

L.E.L., labio-dental lamina, here separated from and well in advance of the dental lamina; *Z.L.*, placed over the shallow dental furrow, points to the dental lamina, which is spread out below to form the enamel germ of the future tooth; *P.p.*, bicuspidate papilla, capped by the enamel germ; *Z.S.*, condensed tissue forming dental sac; *M.E.*, mouth-epithelium.

simultaneously, for the germs of the permanent incisors and canines are formed, along with their papillæ, at about the twenty-fourth week (embryo of 30 c.m.), whereas the enlargements of the dental lamina, which are eventually to form the enamel organs of the first and second premolars, are not visible until the twenty-

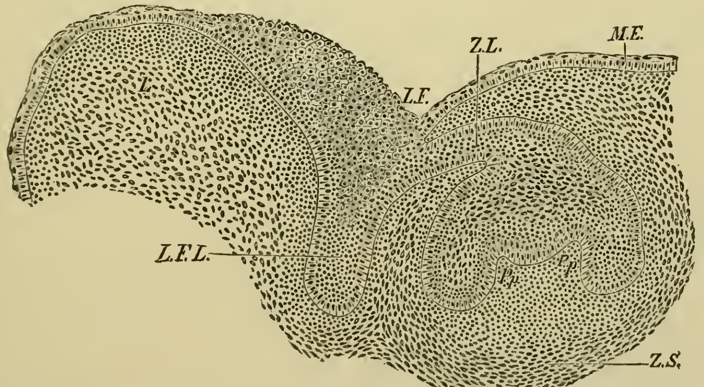


Fig. 61.—Similar section through the canine tooth of an embryo 40 mm. long. (Röse.) $\frac{100}{1}$.

L.F., labio-dental furrow. The other lettering as in Fig. 60.

ninth and thirty-third weeks respectively, and the corresponding papillæ are not formed until the tenth and eighteenth months after birth.

Changes in the connection between the special dental germs and the common dental germ.—The special dental germs are at first simply enlargements of the common germ which grow out on its lingual side. They soon become globular, and rapidly increase in size, and are then connected by a broad tract of cells with the common germ. This *connecting strand* gradually gets thinner and

flatter, and, like the common dental lamina itself, becomes cribriform, so that in sections there appear to be breaches of its continuity. Its connection, however, with the common dental germ, and through this with the buccal epithelium on the one hand and the germ of the corresponding tooth of the secondary dentition on the other hand, long persists. As with the common lamina, this atrophic process begins in connection with the front teeth, and gradually extends backwards, so that at birth the connecting bands of the milk incisors are almost completely broken up, whilst that of the second milk molar is still uninterrupted. The common dental lamina and the bands connecting the special dental germs with it thus become ultimately broken up into separate fragments or islands of dental epithelium of varying size and form. Such "islands" are frequently seen in the infant near the surface of the gum, as pearl-like masses or nests, the so-called "glands of Serres." Normally they have no functional importance, and gradually entirely disappear; but, abnormally, they may give rise to cysts and other new formations, and in some cases fragments of dentine, and even more or less complete teeth, may become developed from them.

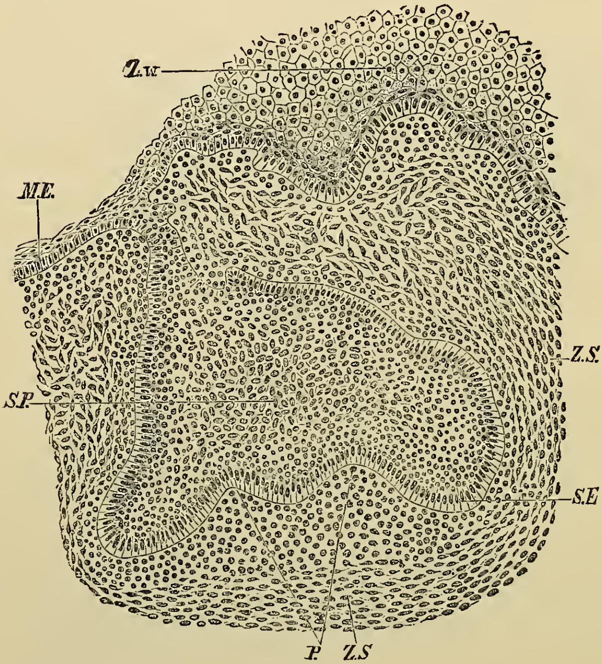


Fig. 62.—Section through the germ of the first milk molar of a cow's fœtus 47 mm. long. (Röse.) $\frac{200}{1}$.

P., bicuspidate papilla; *Z.S.*, dental sac; *M.E.*, mouth-epithelium; *Z.W.*, its thickening over the dental germ, characteristic of Ruminantia; *S.E.*, enamel epithelium; *S.P.*, enamel pulp.

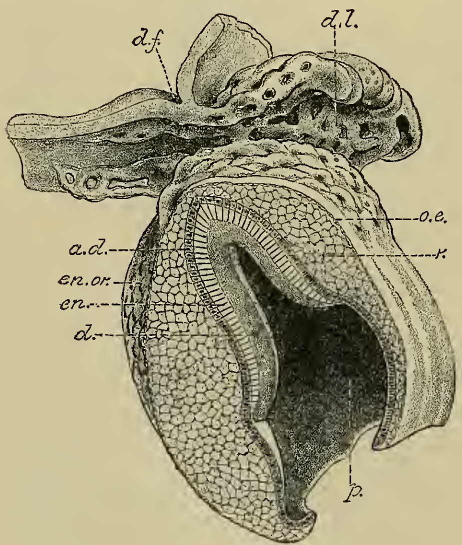


Fig. 63.—Section of second milk incisor of an embryo 30 centimeters long. The epithelial structures only are represented. (From a model by C. Röse.)

d.f., dental furrow in the buccal epithelium; *d.l.*, dental lamina now become cribriform; *p.*, space occupied by the papilla; *d.*, dentine; *en.*, enamel of the developing tooth; *en.or.*, enamel organ, its surface cribriform; *a.d.*, adamantoblasts; *r.*, reticular tissue; and *o.e.*, outer epithelium of the enamel organ.

Changes in connection with the special dental germs.—The special dental germs are at first masses of rounded or polyhedral epithelial cells, but the outermost layer early shows a tendency to be columnar. This becomes pronounced as soon as the papilla begins to make its appearance, and now while the cells which immediately rest upon the papilla become long, regular prismatic columns, the central cells of the germ develop processes, fluid being at the same time secreted between them. The result is the formation of a reticular tissue, which to the naked eye has the appearance of a jelly, to which the name of *enamel-pulp* has been applied (fig. 64, *S.P.*). The more peripheral cells do not participate in this change, but remain polyhedral or become cubical and flattened (*outer enamel epithelium*); they

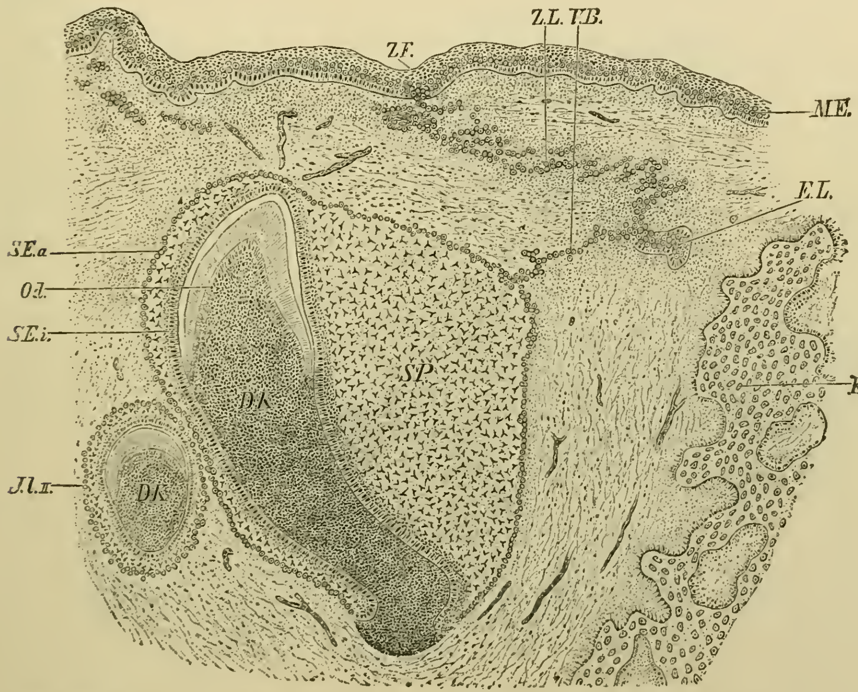


Fig. 64.—Section of the first milk incisor of a human embryo 30 centimeters long. Frontal section through lower jaw. (Röse.)

D.K., papilla; *Od.*, odontoblasts; *K.*, bone of the alveolar process of the jaw; *S.E.a.*, *S.E.i.*, outer and inner layers of the enamel organ; *S.P.*, enamel pulp; *Z.F.*, dental furrow; *M.E.*. mouth-epithelium; *Z.L.*, remains of dental lamina; *V.B.*, cell bridge, connecting this with tooth germ; *E.L.*, reserve germ for the permanent tooth; *J.l.II.*, germ of second milk incisor cut obliquely across.

pass gradually into the long columnar prisms which invest the papilla. These prisms are the cells which form the enamel fibres, and which determine by their presence the production of dentine by the superficial cells of the papilla. They may be termed the *enamel-cells* or *adamantoblasts*; they form the *membrana adamantinæ* of Purkinje. The whole epithelial dental germ thus transformed is known as the *enamel organ* (*organon adamantinæ* of Purkinje). These changes begin in the milk incisors at about 14 weeks. At about 20 weeks (embryo of 24 c.m.) the first traces of calcification are visible in the form of a simultaneous deposit of enamel and of dentine upon the crown of the central incisors. The outer enamel epithelium now begins to grow out into the surrounding connective tissue in the form of epithelial sprouts, and before long there seem to be breaches of continuity between

these sprouts ; but, according to Röse, the enamel-pulp is never invaded by vascular connective tissue, as has been sometimes described.

Changes in the meantime have been occurring in the dental papillæ. These are composed at first of undifferentiated mesoblast ; but their more superficial cells—those which are immediately in contact with the columnar epithelium of the special dental germs—early become elongated, and abut by their distal end against that epithelium, whilst the other end is tapered, and may be branched like the other cells of the embryonic connective tissue. It is from this superficial layer of cells—which in sections have a palisade-like appearance—that the dentine becomes gradually formed, and they have accordingly received the name of *odontoblasts*. There is nothing of the nature of a membrane—the so-called *membrana preformativa*—between the adamantoblasts and the odontoblasts, but the two layers abut at first the one against the other.

Meanwhile the whole tooth-germ—papilla and enamel organ—has become included within a vascular membrane of connective tissue which is known as the *dental sac*.

Formation of the dentine.—The odontoblasts, either by secretion or, as some think, by direct transformation of the peripheral end of each cell, form a layer of dentinal matrix immediately at the surface of the papilla at its apex, or if it have more than one cusp, then at the apex of each cusp. This layer is at first uncalcified,

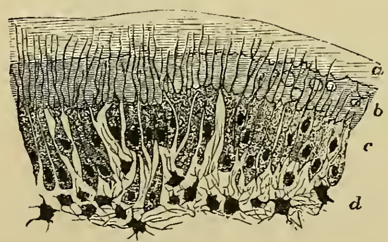


Fig. 65.—Section of developing dentine from the incisor tooth of a young rat. (E. A. S.)

a, outer layer of fully formed dentine ; *b*, uncalcified matrix, with one or two nodules of calcareous matter near the calcified part ; *c*, odontoblasts sending processes into the dentine ; *d*, pulp. The section is stained with carmine, which colours the uncalcified matrix, but not the calcified part.

and is probably the structure which used to be described as membrana preformativa. Globules of calcareous matter soon begin to appear in it. They are at first isolated, but by further deposition of lime salts they become more or less blended into a continuous calcification, which thus forms the first cap of dentine. In the meanwhile the odontoblasts have formed a second layer of uncalcified matrix within the first one, and calcification proceeds in this as in that. In like manner a succession of layers become formed, each one extending laterally rather further than its predecessor, and thus in teeth where there are at first separate deposits for different cusps these become ultimately blended, or as each successive layer is calcified its calcareous deposits blend with that of the preceding and more superficial layers. In places this blending remains incomplete, portions of the dentinal matrix remaining uncalcified between the successive layers ; and in a macerated tooth these portions get destroyed, and cleft-like spaces arise. Since these are bounded by calcified deposit which has been originally laid down in globules, they present a knobbed outline, and are known as interglobular spaces.

As the odontoblasts form the successive layers of dentine in the manner above described, they retire gradually towards the centre. But whilst thus retiring they leave *in situ*, in the layers of forming dentine, filamentous processes of cell-protoplasm, themselves provided with finer side-processes, and the dentinal matrix becomes formed and moulded around these processes, leaving them within tubes which become dentinal tubules, whilst the processes of the odontoblasts become the fibres of Tomes. The same cell continues to spin out such a filament in this manner as long as the formation of dentine continues, each tubule being thus completed in

its whole length from a single odontoblast. In many cases two or more processes are connected with each cell at first, and these coalesce as the cell recedes, the main branches of the dentinal tubules being thus formed.

The other cells of the dental papilla which are not immediately concerned in the formation of dentine become, as the tooth approaches completion, the cells of the dental pulp.

Formation of the enamel.—The prismatic fibres which compose the enamel of the teeth appear to be formed by the direct agency of the ends of the adamantoblasts which abut against the dental papilla. In connection with each of these cells at the end in question a finely globular deposit occurs (Annell), which stains with osmic acid and resembles keratin in its extreme resistance to the action of mineral

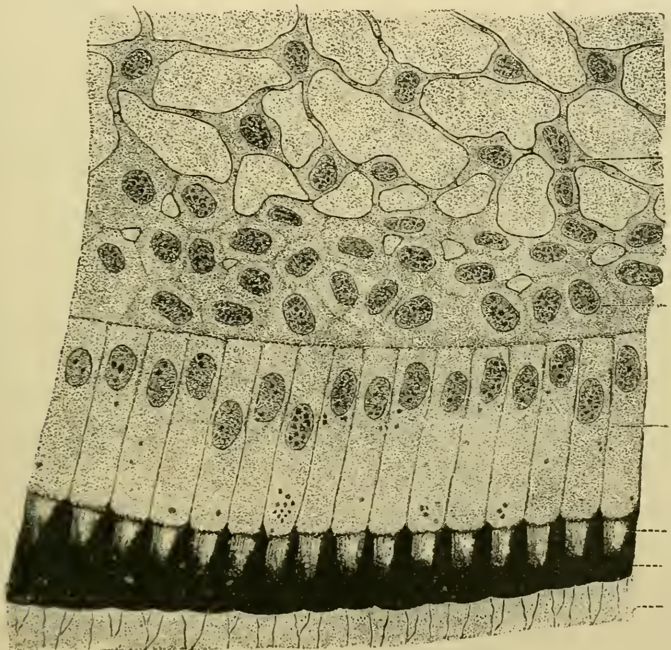
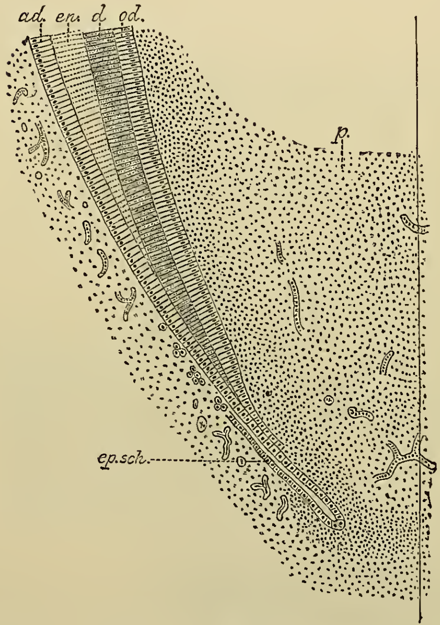


Fig. 66.—Part of the enamel organ of the canine of a young kitten. (Röse.) $\frac{625}{1}$.
d., superficial layer of dentine; *e.*, newly forming enamel stained black by osmic acid; *T.*, Tomes' processes from the adamantoblasts, *ad.*; *str.int.*, stratum intermedium of the enamel organ; *p.*, branched cells of the enamel pulp.

acids (*enamel droplets*, v. Spee). The layer which is thereby formed, and which is not yet calcified, is outside the main body of the adamantoblasts—although a process from each adamantoblast extends into it as a tapering fibre (*process of Tomes*)—and it is usually produced simultaneously with the first layer of uncalcified dentine against which it is applied. Before long it undergoes calcification, and the first layer of enamel is then complete. After a time the adamantoblasts yield a second layer of keratin-like material, and from this after calcification has invaded it, another stratum of enamel is formed, and so on. As with the dentine, the formation of enamel appears first at the apex of each cusp, so that there are at first as many caps as cusps. Whilst these changes are being effected, the adamantoblasts gradually retire as the successive layers of the enamel are being produced by them, and this gradual shifting goes on as long as the formation of enamel continues—that is to say, until the crown of the tooth is completed. By this time the enamel pulp has greatly

diminished, and in fact almost disappeared, and the remainder of the enamel organ forms a thin epithelial cap over the crown, which soon disappears on the emergence of the tooth beyond the gum. But besides this epithelial cap, and underneath it, there is a very thin membrane, which is more persistent, and covers the crowns of the teeth for some little while after their emergence (fig. 52, *e, e*). This is *Nasmyth's membrane*, or the *enamel cuticle*, and, according to v. Brunn, it is the last formed keratinous layer of enamel which has remained uncalcified.



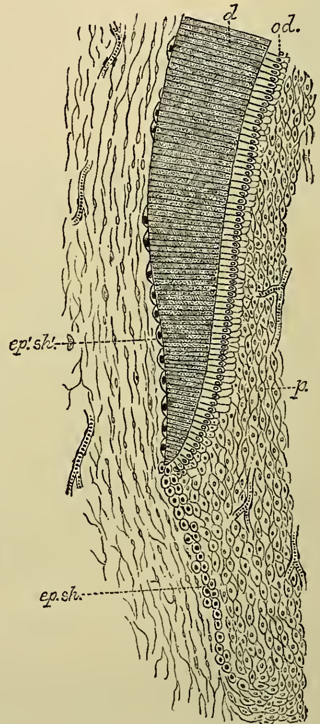


Fig. 67.—Longitudinal section of the lower part of a growing tooth, the crown of which is formed, showing the extension of the layer of adamantoblasts beyond the crown to mark off the limit of formation of the dentine of the root. (Röse.)

p., pulp ; *od.*, odontoblasts ; *d.*, dentine ; *en.*, enamel ; *ad.*, adamantoblasts, continuous below with, *ep.sch.*, the epithelial sheath of Hertwig.

Fig. 68.—Section similar to that shown in fig. 67, but from a tooth more advanced in growth.

ep. sh., epithelial sheath ; *ep.' sh'.*, remnants of this, overlying dentine of fang.

It has usually been considered (Tomes, Waldeyer and others) that the enamel prisms are formed by direct calcification *in situ* of the inner ends of the adamantoblasts, the outer nucleated end growing *pari passu* with the extent of the inner end which has thus been converted into enamel. But a different view has been taken by some authorities, viz. that the layer of adamantoblasts sheds out the substance within which calcareous matter is subsequently deposited ; the enamel prisms being formed therefore rather as a secretion from the adamantoblasts than by transformation *in situ*. This is supported by the readiness with which the adamantoblasts separate from the enamel, but on the other hand it is more difficult if it is accepted to account for the fact that the enamel prisms take the exact diameter and shape of the adamantoblasts. The view seems to me to be corroborated by appearances seen in sections which have been placed at my disposal by Mr. J. L. Williams, which show a well-marked layer of highly refractive globules imbedded in a fibrinous-looking matrix lying between the adamantoblasts and the already formed strata of enamel.

Formation of the cement.—The roots of the teeth are gradually formed shortly before the time for the emergence of the crowns beyond the gum, but they

are not completed until long after the crowns have come through. They are determined in their form—moulded, as it were—by a growth of the epithelium of the dental germ, which extends in the form of a fold, the so-called *epithelial sheath*, (fig. 67) towards the future apex of each fang (v. Brunn). On the inner or papilla surface of this sheath odontoblasts form dentine, as in the crown, and thus the root is gradually produced. The epithelial sheath becomes gradually atrophied and ultimately broken up into isolated portions, which may be seen occasionally, even in the adult, as epithelial islands, in the connective tissue of the dental periosteum (fig. 55).

C. Tomes has shown that an epithelial sheath is formed in the same manner, even in the teeth of animals (*e.g.*, Taturia) in which the dental germ produces no enamel at all.

After the formation of the dentine of the root has begun, the vascular tissue of the dental sac begins to break through the epithelial sheath near the crown, and forms a layer of bone-forming tissue at the surface of the newly-deposited dentine. The osteoblasts of this tissue deposit layers of true bone, with osteogenic fibres, lacunæ, and canaliculi, upon the surface of the dentine of the root, and these layers form the cement of the fang. The very apex of each fang, which is the last part to be produced, is formed wholly of cement, for the epithelial sheath which determines the formation of dentine, never extends quite as far as the permanent apex.

In some animals the cement of the teeth is preceded by the formation of cartilage, which becomes ossified as in the endochondral formation of bone (Magitot, v. Brunn). According to Magitot, in animals such as ruminants in which the cement covers the crown, a special cartilaginous "cement organ" is developed for the production of this cement. It is questionable, however, whether the cartilaginous tissue which gives origin to this cement is sufficiently specialized to deserve a distinct name.

The **dental sacs** are well seen in the jaw of an infant a few months old, before the eruption of the teeth. They are represented at this state in fig. 69. They

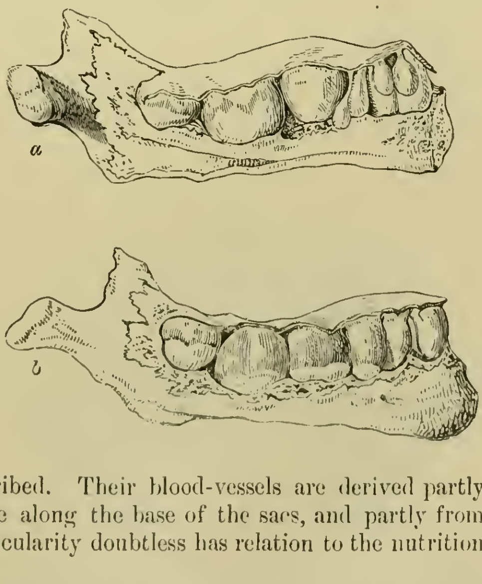


Fig. 69.—The dental sacs exposed in the jaw of a child at birth.

a, the left half seen from the inner side; *b*, the right half shown from the outer side; part of the bone has been removed so as to expose the dental sacs as they lie below the gum; the lower figure shows the sacs of the milk teeth and the first permanent molar, exposed by removing the bone from the outside; the upper figure shows the same from the inside, together with the sacs of the permanent incisor and canine teeth adhering to the gum.

consist of an outer fibro-vascular coat connected with the periosteum, and an inner highly vascular layer with a little jelly-like tissue interposed between the two. The inner coat is lined with the epithelium of the enamel organ to be hereafter described. Their blood-vessels are derived partly from the dental arteries which course along the base of the sacs, and partly from those of the gums. Their extreme vascularity doubtless has relation to the nutrition of the enamel organ.

At birth the crowns of all the milk incisors and canines are fairly advanced in calcification. The separated cusps of the milk molars have also blended, and the calcification of the first permanent molar is just beginning in the form of separate

caps for each cusp, one of which has usually appeared at birth, and the others follow shortly after. These, however, do not run together until six months after birth.

The germs of the permanent incisors and canines are visible to the naked eye at birth, lying behind and slightly lateral to the corresponding milk-teeth ; but there is no trace as yet either of the premolars or of the second permanent molar. The last-mentioned makes its appearance between four and six months after birth, the papilla of the first premolar about the tenth month, and that of the second premolar about the eighteenth month. At two years, when the second milk molars are just coming through the gum, the crown of the first permanent molar is finished, but there are still only isolated cusps on the second permanent molar of the upper jaw, and none on the second permanent molar of the lower jaw. In the premolars also the (two) cusps are still separate at this time.

The various phases in the formation of the teeth occur almost simultaneously in the corresponding teeth of both jaws.

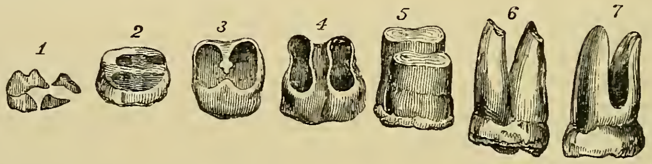


Fig. 70.—Different stages in the formation of a molar tooth with two fangs. (From Blake. 1, the distinct caps of dentine for five cusps in the earliest stage of formation ; in 2, and the remaining figures, the crown is downwards ; in 2 and 3, the formation of the crown having proceeded as far as the neck, a bridge of dentine stretches across the base of the tooth-pulp ; and in 4, the division of the fangs is thus completed ; in 5, 6, and 7, the extension takes place in the fangs.

Formation of the alveoli.—All the tooth germs are at first included in a common trough or groove, which encloses the whole dental lamina and the adjacent connective tissue. This begins to be formed at about 14 weeks (embryo of $11\frac{1}{2}$ c.m.). Bony septa subsequently become formed and subdivide the trough into loculi, but even at birth these septa are incomplete, and up to this time, and even later, both the milk tooth and the corresponding permanent tooth germ are enclosed in the same loculus. As the fangs become developed the loculi deepen and also become subdivided to form separate cavities for the teeth of both first and second dentition. Around the milk-teeth they become narrowed to form alveoli which

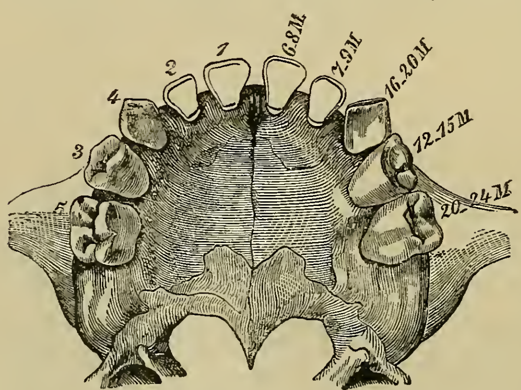


Fig. 71.—Diagram (after Welcker) showing on the left side the order, and on the right side the time (in months) of appearance of the milk teeth of the upper jaw. (Rauber.)

closely invest the roots ; but although the whole of the developing tooth is at one time embedded in the cavity of the alveolus, the bone never completely closes over it, an aperture being always left over the crown, through which the dental sac is connected by soft tissues with the surface of the gum. In the same way, when the teeth of the second dentition become invested within alveoli, these always have a narrow opening through which the so-called *gubernaculum dentis*, a band of connective tissue containing remains of the common dental lamina, passes.

Eruption of the milk-teeth.—The eruption of the teeth does not occur in regular succession from behind forwards, and by a gradual and continuous process, but in batches, with intervals of repose between the successive batches. The following shows the most usual time of eruption (C. S. Tomes). The first to appear are the lower central incisors, at six to nine months. Their eruption is rapid, and is completed in about ten days; then follows a resting period of two or three months, after which the upper incisors appear, both central and lateral. Then, after a rest of a few months, come the lower lateral incisors and the first molars; then, after four or five months, the canines, and finally, about the second year, the second molars.

Table of Eruption of the Milk-Teeth.

Lower central incisors	6 to 9 months.
Upper incisors	8 to 10 months.
Lower lateral incisors and first molars. . .	15 to 21 months.
Canines	16 to 20 months.
Second molars	20 to 24 months.

Development of the permanent Teeth.—Ten permanent teeth in each jaw

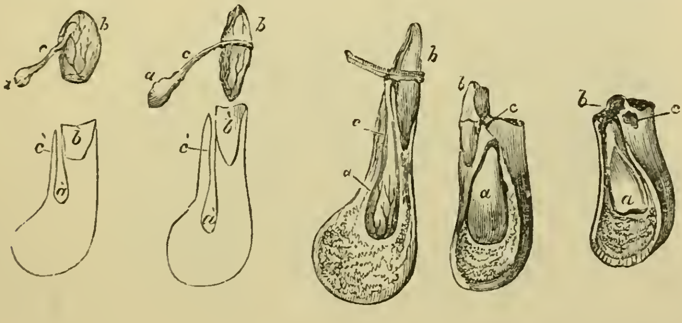


Fig. 72.—Sketches showing the relations of the temporary and permanent dental sacs and teeth. (After Blake, with some additions.)

The lower parts of the first three figures, which are somewhat enlarged, represent sections of the lower jaw through the alveolus of a temporary incisor tooth: *a*, indicates the sac of the permanent tooth; *c*, its pedicle; *b*, the sac of the milk tooth or the milk tooth itself; *a′*, *b′*, indicate the bony recesses in which the permanent and temporary teeth are lodged, and *c′*, the canal by which that of the former leads to the surface of the bone behind the alveolus of the temporary tooth. The fourth and fifth figures, which are nearly of the natural size, show the same relations in a more advanced stage, in IV., previous to the change of teeth, in V., when the milk-tooth has fallen out and the permanent tooth begins to rise in the jaw; *c*, the orifice of the bony canal leading to the place of the permanent tooth.

succeed the milk-teeth, and six are superadded further back in the jaw. It will be convenient to treat first of the ten anterior teeth or *teeth of succession*.

The sacs and pulps of these teeth have their foundations laid before birth in the way already described. It will be remembered that behind and lateral to each milk-follicle there is found about the sixteenth week a thickening of the common dental lamina (pp. 40, 41, and fig. 64, *E.L.*), and this forms the enamel-germ of the corresponding permanent tooth. They are ten in number in each jaw, and are formed successively from before backwards. These germs soon elongate and recede into the substance of the gum behind the germs of the milk-teeth. In the meantime, a papilla is formed at the bottom of each enamel germ (that for the central incisor appearing first) and the germs become each enclosed within a dental sac, the sac of the permanent tooth adhering to the back of that for the temporary tooth.

The bone of the jaw not only forms a cell for the reception of the milk sac, but ultimately also a small posterior recess or niche for the permanent tooth-sac, with which the recess keeps pace in its growth. In the lower jaw, to which our description may now, for convenience, be confined, the permanent sac is at length found at some distance below and behind the milk-tooth ; the sac for the permanent tooth acquiring at first a pear-shape, and being then connected with the gum by a solid pedicle of fibrous tissue (fig. 72, I., II., *c*). The recess in the jaw (a') has a similar form, drawn out into a long canal for the pedicle, which opens on the edge of the jaw, by an aperture behind the corresponding milk-tooth. The permanent tooth is thus separated from the socket of the milk-tooth by a bony partition, which, as well as the root of the milk-tooth just above it, becomes absorbed as the crown of the permanent tooth rises through the gum. When this has proceeded far enough, the milk-tooth becomes loosened, falls out or is removed, and the permanent tooth takes

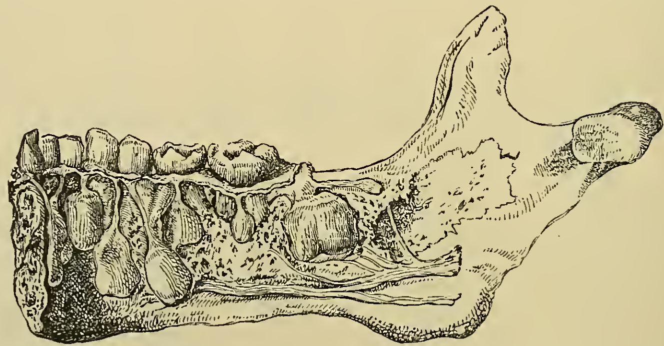


Fig. 73.—PART OF THE LOWER JAW OF A CHILD OF THREE OR FOUR YEARS OLD, SHOWING THE RELATIONS OF THE TEMPORARY AND PERMANENT TEETH.

The specimen contains all the milk-teeth of the right side, together with the incisors of the left ; the inner plate of the jaw has been removed, so as to expose the sacs of all the permanent teeth of the right side, except the eighth or wisdom-tooth, which is not yet formed. The large sac near the ramus of the jaw is that of the first permanent molar, and above and behind it is the commencing rudiment of the second molar.

its place. The absorption of the dental substance commences at or near the ends of the fangs, and proceeds upwards until nothing but the crown remains. The cement is first attacked, and then the dentine ; but the process is similar in the two tissues. The change is not produced merely by pressure, but, as in the case of the absorption of bone, through the agency of multi-nucleated absorbing cells or osteoclasts, developed at the time, and applied to the surface of the fang. The sockets begin to be formed around the neck of the tooth as soon as the crown projects, and are formed simultaneously with the developing fangs.

The six posterior (or *superadded*) permanent teeth, that is, the three permanent molars on each side, do not come in the place of other teeth. They arise from successive extensions of the common dental lamina carried backwards in the jaw behind the milk-teeth.

The part of the common lamina posterior to the last temporary molar long continues unobliterated, and from it there becomes developed at about the seventeenth week of embryonic life a special enamel germ which forms the rudiment of the first permanent molar tooth (fig. 57, 4, m^1). After a long interval, viz., about the fourth month after birth, the germ for the second permanent molar tooth appears in the dental lamina, which is now projecting backwards from the neck of that for the first molar. After another long interval, during which the sac of the first permanent molar and its contained tooth have acquired great size, and that of the

second molar has also advanced considerably in development, the same changes once more occur and give rise to the sac and papilla of the wisdom-tooth (third year). The subsequent development of the permanent molar teeth takes place within their sacs just like that of the other teeth. In exceptional instances, a fourth molar may be formed in like manner in a further backward extension of the dental lamina.

After all the teeth of the second dentition are thus formed, the dental lamina generally ceases to form more special enamel germs and gradually atrophies in the manner already described. But in rare instances a third series of germs make their appearance postero-lateral to the teeth of the second dentition, and a third complete series of teeth may result therefrom.

Calcification begins first in the anterior permanent molar teeth. Its order and

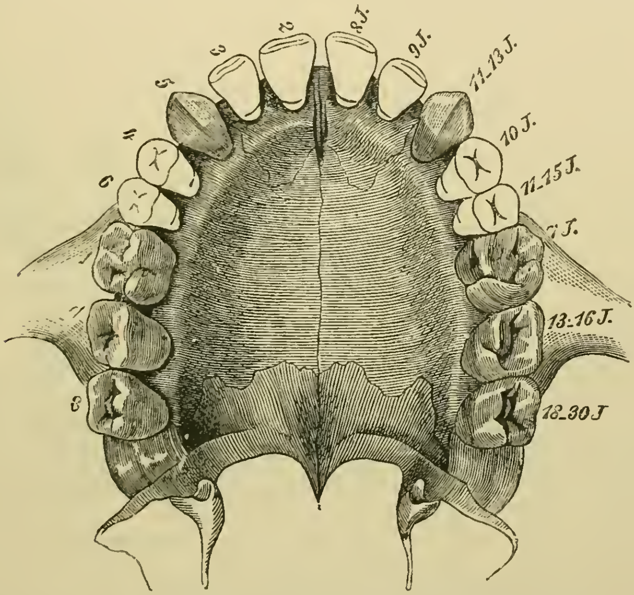


Fig. 74.—Diagram from Welcker, showing on the left side the order, and on the right side the time (in years) of appearance of the permanent teeth of the upper jaw. (Rauber.)

periods may be thus stated : First molar, one cusp shows calcification at birth, the rest soon after birth ; central incisor, lateral incisor, and canine, about six months after birth, the central incisors first, the canines last ; bicuspids, two years or more ; second molar, two years ; third molar, or wisdom-tooth, about twelve years.

Eruption of the permanent Teeth.—The time at which this occurs in regard to each pair of teeth in the lower jaw is exhibited in the subjoined table. The corresponding teeth of the upper jaw appear somewhat later :—

Molar, first	6 years.
Incisors, central	7 ,,
,, lateral	8 ,,
Bicuspids, anterior	9 ,,
,, posterior	10 ,,
Canines	11 to 12 ,,
Molars, second	12 to 13 ,,
,, third (or wisdom)	17 to 25 ,,

It is just before the shedding of the temporary incisors—*i.e.*, about the sixth

year, that there is the greatest number of teeth in the jaws. At that period there are all the milk-teeth, and the crowns of all the permanent set except the wisdom-teeth, making forty-eight (see fig. 75).

During the growth of the teeth the jaw increases in depth and length, and undergoes changes in form. In the child it is shallow, but it becomes much deeper in the adult. In the young subject the alveolar arch describes almost the segment of a circle ; but in the adult the curve is semi-elliptical. The increase which takes place in the length of the jaw arises from a growth behind the position of the milk-teeth, so as to provide room for the three additional

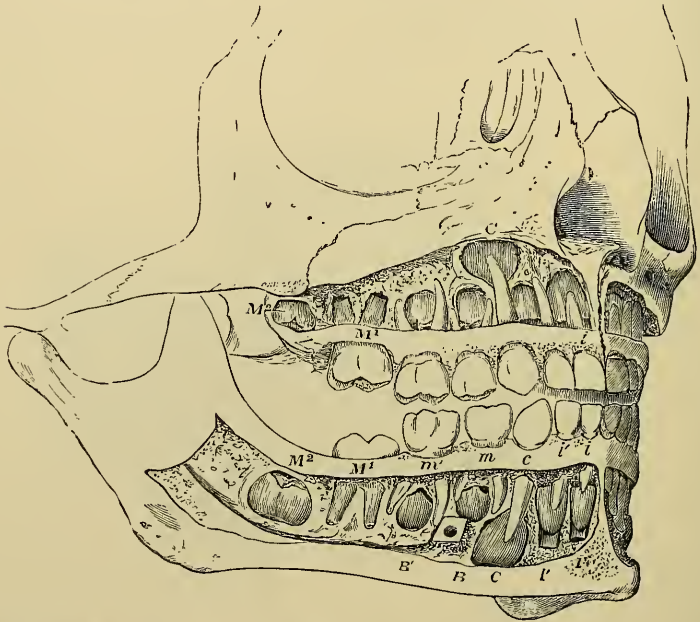


Fig. 75.—The teeth of a child of six years, with the calcified parts of the permanent teeth exposed. (After Henle, and modified from nature, A. T.)

The whole of the teeth of the right side are shown, together with the three front teeth of the left side : in the upper and lower jaws the teeth are indicated as follows :—1, *milk-teeth*—*i*, inner or first incisor ; *i'*, outer or second incisor ; *c*, canine ; *m*, first molar ; *m'*, second molar. 2, *permanent-teeth*—I, inner or first incisor ; I', outer or second incisor ; C, canine ; B, first bicuspid ; B', second bicuspid ; M^1, the first molar, which has passed through the gums ; M^2, the second molar, which has not yet risen above the gums ; the third molar is not yet formed.

teeth on each side belonging to the permanent set. At certain periods in the growth of the jaws there is not sufficient room in the alveolar arch for the growing sacs of the permanent molars ; and hence the latter are found enclosed in the base of the coronoid process of the lower jaw, and in the maxillary tuberosity of the upper jaw, but they afterwards successively assume their ultimate position as the bone increases in length. The space taken up by the ten anterior permanent teeth very nearly corresponds with that which had been occupied by the ten milk-teeth ; the difference in width between the incisors of the two sets being compensated for by the smallness of the bicuspids in comparison with the milk-molars to which they succeed. Lastly, the angle formed by the ramus and body of the lower jaw differs at different ages ; thus it is obtuse in the infant, approaches nearer to a right angle in the adult, and again becomes somewhat obtuse in old age (see Vol. II, p. 78).

Historical.—The first complete account of the development of the teeth was given by Goodsir (*Edin. Med. and Surg. Journal*, 1838), who described the formation of a groove in the mucous membrane of the jaw, the formation of special depressions in this groove corresponding to the milk-teeth. the appearance of papillæ within these, the enclosure of the papillæ within follicles covered by membrane, and finally the time and mode of eruption of the several teeth.

Goodsir's results, which, so far as they went, were fairly accurate, were obtained from specimens which had been badly preserved, and in which the epithelium, which is now regarded as the important element in tooth formation, had become detached in consequence of maceration.

The views of Goodsir prevailed until 1863, when Kölliker (Gewebelehre) clearly showed the important part taken by the involution of the Malpighian layer of the epithelium of the jaw in the formation both of the common and of the special enamel germs. (This had been already pointed out by Marcusen (Bull. de l'Acad. de Pétersbourg, 1849) and by Huxley (in fishes and reptiles, *Quar. Jour. of Micr. Sci.*, 1853), but was nevertheless not generally accepted.) Kölliker's results were confirmed and extended by the work of Waldeyer, Kollmann, Magitot, C. S. Tomes, and others. Baume first pointed out the independent origin of the teeth of succession from the common dental lamina ; previous observers had followed Kölliker (and Goodsir) in ascribing the origin of their germs to the special germs of the milk-teeth. Pouchet and Chabry were the first to describe the common origin of the labio-dental furrow and the common dental lamina. Finally, the most important details regarding the origin of the human teeth are to be met with in the works of Magitot and Legros and of Röse. Röse's account is based upon sections of the jaw of embryos of various ages, from which he has constructed models showing several stages of development in a strikingly objective form ; figures of some of these models have here been reproduced.

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THE PHARYNX.

The **pharynx** (figs. 76, 77, 78 and 80) extends from the base of the skull to the lower border of the sixth cervical vertebra, where it terminates by becoming continuous with the œsophagus. It lies in front of the lower part of the basilar process of the occipital bone and the upper six cervical vertebræ and behind the nasal cavities, mouth, and larynx. It may therefore be divided into three parts, viz., nasal, oral, and laryngeal. The soft palate projects backwards and downwards into it, and during the act of deglutition is drawn upwards and backwards against its posterior wall, so as to completely separate the nasal from the oral portion. In all, seven openings lead into the cavity of the pharynx, viz., above the velum, the two posterior nares (*choanæ*) and the two Eustachian tubes, and below the velum, from above downwards, the orifices leading into the mouth, larynx, and œsophagus. The pharynx is about five inches (14 centimeters) in length. Its transverse diameter is considerably greater than its antero-posterior. Its widest part is opposite the laryngeal aperture, below which it rapidly contracts like a funnel towards its termination, where it is narrowest.

The **nasal part of the pharynx** (*naso-pharynx* or *post-nasal space*) is an air cavity irregularly cubical in shape, which cannot be obliterated by muscular action, although its floor can be raised and depressed by the muscles of the soft palate. Its anterior wall shows the posterior edge of the nasal septum with the posterior nares, one on either side. In the posterior wall the mucous membrane is thickened and thrown into a number of folds, chiefly vertical in direction. As these folds contain a considerable quantity of lymphoid tissue they are often called the *pharyngeal tonsil*. A well-marked recess of the mucous membrane, known as the *pharyngeal bursa* (*recessus pharyngeus medius*), which is constant in the fœtus and young subject, and is occasionally present in the adult, extends from just below the pharyngeal tonsil upwards in the middle line as far as the pharyngeal tubercle.

This recess was regarded by Luschka (Der Schlundkopf d. Menschen, 1868, p. 26) as a rudiment of the invagination from which is developed the anterior part of the pituitary body. This idea is now generally abandoned in favour of the view that it is connected with the formation of the pharyngeal tonsil. Killian (Morph. Jahrb., Bd. xiv, 1888, p. 618), however, has shown that the pharyngeal tonsil may exist in the human fœtus and also in animals without any traces of a pharyngeal bursa.

The opening of the *Eustachian tube* appears as a vertical cleft, or as a funnel-shaped opening, in the lateral wall, and is bounded behind by a prominence—the *cushion of the Eustachian orifice*—containing the cartilage of the tube. Between this prominence and the posterior wall of the pharynx there is a deep recess passing backwards and outwards. It is known as the *lateral recess of the pharynx* (*fossa of Rosenmüller*). This recess represents the upper part of the pharyngeal portion of the second visceral cleft, the Eustachian tube being formed from the first cleft. From the cushion of the Eustachian orifice the mucous membrane forms a vertical fold, the *plica salpingo-pharyngea*, passing downwards on the side wall of the pharynx behind the posterior palatine arch.

When the levatores palati are contracted, the upper surface of the soft palate presents a convex eminence behind each posterior naris, called the *levator cushion*. This is occasionally seen in the dead body.

The average capacity of the nasal part of the pharynx is said to be 14 cubic centimeters. Its transverse diameter in front of the Eustachian orifices is about 22 mm.; between the Eustachian cushions it varies considerably—on an average it is about 15 mm. The distance from the lower part of the posterior edge of the nasal septum to the posterior wall of the pharynx is 15 mm.

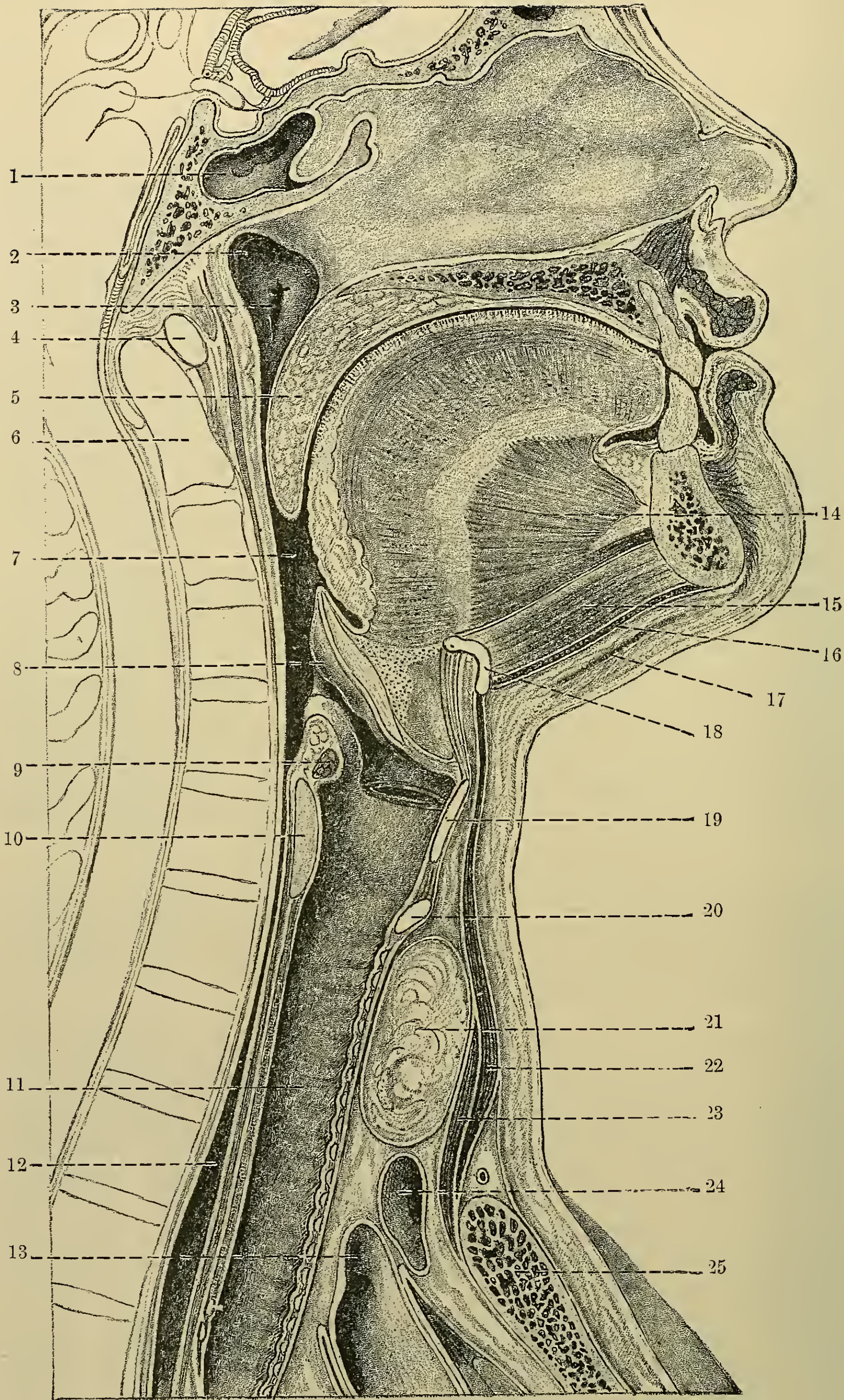

Fig. 76.—MEDIAN SECTION OF THE HEAD AND NECK. (Braune.) $\frac{2}{3}$

1, sphenoidal sinus; 2, lateral recess of pharynx; 3, pharyngeal orifice of Eustachian tube; 4, anterior arch of atlas; 5, soft palate; 6, body of axis; 7, oral portion of pharynx; 8, epiglottis; 9, arytenoid muscle; 10, cricoid cartilage; 11, trachea; 12, œsophagus; 13, origin of innominate artery from aorta; 14, genio-glossus muscle; 15, genio-hyoid muscle; 16, mylo-hyoid muscle; 17, platysma; 18, hyoid bone; 19, thyroid cartilage; 20, cricoid cartilage; 21, isthmus of thyroid body; 22, sterno-hyoid; 23, sterno-thyroid; 24, left innominate vein; 25, manubrium sterni.

The **oral part of the pharynx** is situated below the soft palate and above the level of the larynx. Owing to the mobility of its walls it is very variable in form and size. In front it communicates with the mouth through the isthmus of the fauces, and below this opening it is bounded anteriorly by the posterior part of the

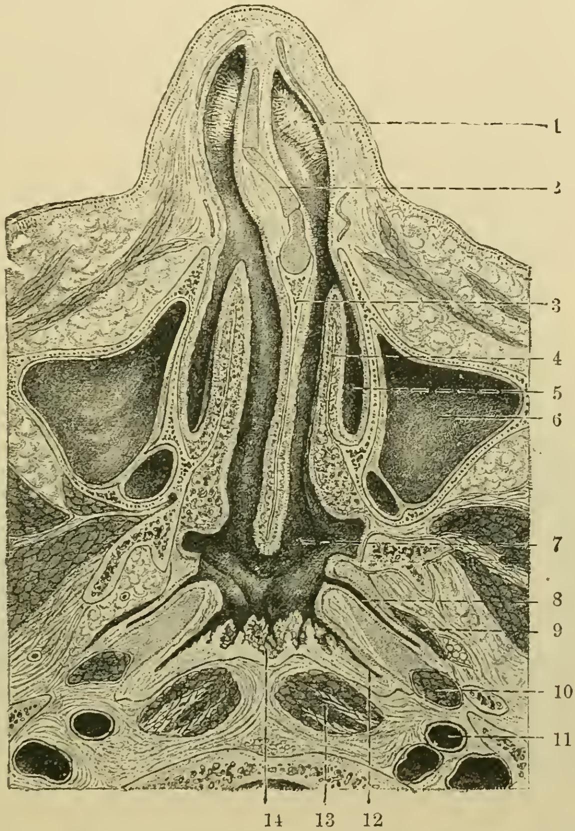

Fig. 77.—Horizontal section through nasal cavities and nasal portion of pharynx, seen from above. (J. S.) $\frac{7}{8}$

1, anterior naris; 2, septal cartilage; 3, vomer; 4, inferior concha; 5, inferior meatus; 6, maxillary antrum; 7, posterior naris; 8, Eustachian tube; 9, tensor palati; 10, levator palati; 11, internal carotid artery; 12, lateral recess of pharynx; 13, rectus anticus major; 14, pharyngeal tonsil.

dorsum of the tongue. On its lateral wall there is a somewhat triangular recess bounded by two folds of mucous membrane, called the *anterior* and *posterior palatine arches.* Both these folds are connected above with the soft palate, and diverge as they pass downwards. The anterior arch joins the tongue and forms the lateral boundary of the isthmus of the fauces, while the posterior one gradually disappears on the side wall of the pharynx.

The **tonsils** (*tonsillæ, amygdalæ*) are two prominent bodies situated in the recess between the anterior and posterior palatine arches. They are usually from 20 to 25 mm. in vertical extent, reaching from the soft palate above to the level of the top of the epiglottis below; they measure about 15 mm. from before backwards and rather less than this from within outwards, but they vary much in different individuals. The free inner surface of the tonsil has a variable number of slit-like or

rounded orifices which lead into recesses or crypts in the substance of the tonsil (fig. 78, *16* ; fig. 79). The outer surface is connected with the inner aspect of the superior constrictor of the pharynx, external to which is the internal pterygoid muscle. Both the external and internal carotid arteries lie fully an inch external and posterior to the tonsil. The tonsils extend downwards as low as the angle of the jaw, but they cannot, even when enlarged, be felt from the surface of the neck at this point.

Above the tonsil there is frequently a recess directed upwards and backwards, and called the *fossa supra-tonsillaris.* It is considered by His to be the remains of the lower part of the second visceral cleft. The fold of mucous membrane covering this recess is named *plica triangularis.*

Vessels and nerves.—Arteries.—These structures receive a very large supply of blood from various arteries, viz., from the tonsillar and palatine branches of the

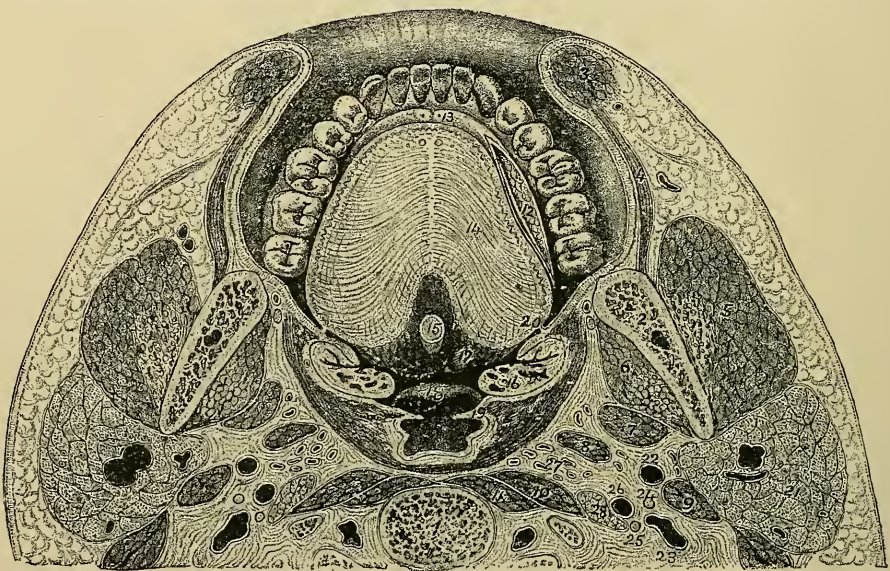

Fig. 78.—Horizontal section through the mouth, pharynx, &c., just above the teeth of the lower jaw. The section is viewed from above. (J. S.) $\frac{2}{3}$

1, Body of axis ; 2, ramus of lower jaw ; 3, orbicularis oris ; 4, buccinator ; 5, masseter ; 6, internal pterygoid ; 7, stylo-glossus ; 8, stylo-pharyngeus ; 9, digastric and stylo-hyoid ; 10, rectus capitis anticus major ; 11, longus colli ; 12, sublingual gland, and on its inner side Wharton's duct ; 13, aperture of Wharton's duct ; 14, muscular substance of tongue ; 15, tip of uvula ; 16, tonsil (somewhat enlarged) ; 17, root of tongue ; 18, epiglottis ; 19, posterior palatine arch ; 20, anterior palatine arch ; 21, parotid gland ; 22, external carotid artery ; 23, internal jugular vein ; 24, hypoglossal nerve ; 25, vagus ; 26, internal carotid artery ; 27, pharyngeal veins ; 28, lymphatic gland.

facial artery, the descending palatine of the internal maxillary, the ascending pharyngeal and the dorsal artery of the tongue. From these arteries fine branches and capillaries are distributed abundantly to the lymphoid tissue and follicles and to the papillæ of the mucous membrane which lines the recesses. The **veins** are numerous, and enter the tonsillar plexus on its outer side. The **nerves** come from the glosso-pharyngeal nerve, and from the fifth. **Lymphatics** are abundant, and surround the follicles with a close plexus ; they eventually pass into the superior deep cervical lymphatic glands.

Structure.—The tonsils are composed of a spongy connective tissue infiltrated with lymphoid cells, which are collected at frequent intervals into nodules or follicles, in which the lymphoid tissue is denser than elsewhere. These nodules, as in other situations where they occur, represent germinating centres in which the

lymphoid cells are most rapidly multiplying. Extending inwards from the surface are tubular or cleft-like crypts, which are lined with stratified epithelium similar to that of the surface, and the walls of which are beset with lymphoid nodules. Into these crypts mucous glands open, but these are not very numerous. The lymphoid cells are constantly passing in large numbers through the epithelium, to become free at the surface and on the crypts of the tonsils (Stöhr) ; in this way they pass into the mouth and mix with the saliva to form the so-called salivary corpuscles.

The **laryngeal part of the pharynx** is situated behind the entire extent of the larynx. Its length is equal to that of the nasal and oral parts combined. In the upper part of its anterior wall is the superior aperture of the larynx. On either

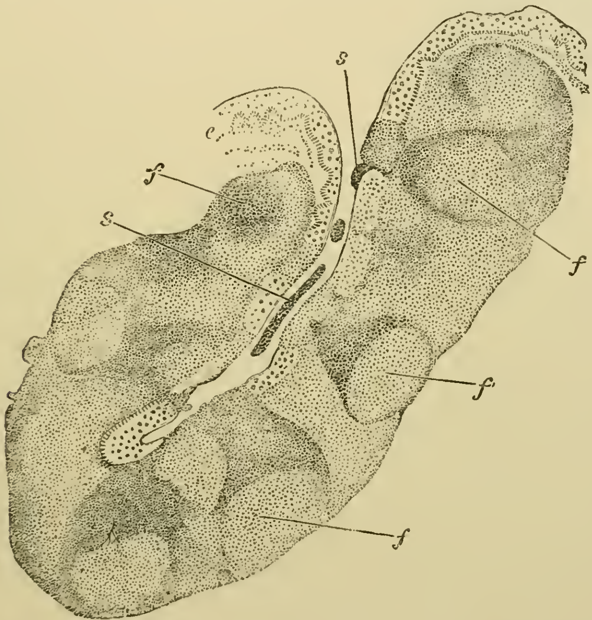

Fig. 79.—Section through one of the crypts of the tonsil, magnified. (Stöhr.)
e, stratified epithelium of general surface, continued into crypt ; f, f, follicles or nodules of lymphoid tissue ; opposite each nodule or germ-centre numbers of lymph-cells are passing into and through the epithelium ; s, s, masses of cells which have thus escaped from the tonsil to mix with the saliva as salivary corpuscles.

side of this is a longitudinal groove called the *sinus pyriformis*, which represents the remains of the fourth visceral cleft (His).

Opposite the laryngeal aperture the transverse diameter of the pharynx is about 3·6 c.m. Below this opening the anterior and posterior walls of the pharynx are in contact, but the transverse diameter undergoes only a very slight diminution as far down as the cricoid cartilage, behind which it rapidly contracts so that at its termination it is only about 12 to 16 mm.

Varieties.—The principal variations of the pharynx are due to the abnormal persistence of the visceral clefts or irregularities in their position. Various cases of this kind have been described as pharyngeal diverticula or cervical fistulæ (for literature, see von Kostanecki).

Structure and attachments.—The walls of the pharynx are formed from within outwards of a mucous membrane, a layer of fibrous tissue called the *pharyngeal aponeurosis*, a muscular coat, and another layer of fibrous tissue, which with that covering the buccinator muscle, is called *bucco-pharyngeal fascia* (see Vol. II,

p. 307). The pharyngeal aponeurosis is thin and lax below, but becomes thicker and denser above, where it is attached to the posterior part of the sphenoid bone and passes outwards to the petrous portion of the temporal bone and on to the Eustachian tube. It is strengthened in the middle line by a strong band descending

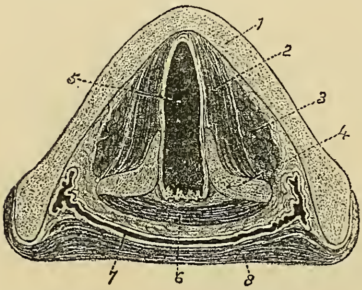

Fig. 80. — Horizontal section of the larynx and laryngeal part of pharynx. (J. S.)

1, thyroid cartilage; 2, thyro-arytenoid muscle; 3, lateral crico-arytenoid muscle; 4, arytenoid cartilage; 5, rima glottidis; 6, arytenoid muscle; 7, cavity of laryngeal part of pharynx; 8, inferior constrictor of pharynx.

between the recti antici muscles from a part of the basilar process of the occipital bone, which often presents a marked tubercle.

Behind, the bucco-pharyngeal fascia is connected by a very loose areolar tissue to the prevertebral fascia, covering the bodies of the cervical vertebra and the muscles which rest upon them. At the sides it has similar connections with the styloid process and its muscles, and with the sheaths of the large vessels and nerves of the neck.

The attachments and relations of its muscular coat are described in Vol. II, Part ii. Its mucous membrane is continuous at the several apertures with those of the adjacent cavities.

Structure of the mucous membrane of the pharynx.—The mucous membrane of the pharynx is formed by connective tissue, provided with low papillæ and covered by epithelium, which is stratified over the greater part of the cavity, but ciliated in the upper or naso-pharynx. The back of the soft palate also has a covering of stratified epithelium in the adult, although in the fœtus it is ciliated. Ciliated epithelium has been described in some of the gland ducts both here and in other parts of the pharynx in the adult. Numerous racemose mucous glands occur under the mucous membrane; they are especially abundant above, near the Eustachian tube, but they are found in all parts. Lymphoid tissue is also abundant in the upper part and back of the pharynx; a large collection of lymph-follicles stretches across the back of the cavity between the orifices of the Eustachian tubes (pharyngeal tonsil). This is apt to become hypertrophied in children, and to block those orifices, and even the posterior nares.

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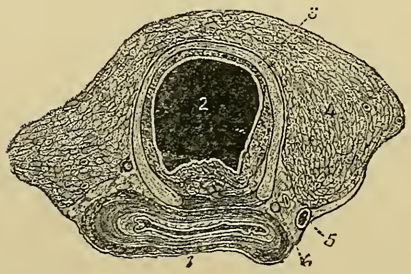
THE ŒSOPHAGUS.

The **œsophagus** or **gullet** is the part of the alimentary canal leading from the pharynx to the stomach. It commences at the level of the lower border of the cricoid cartilage, opposite the disc between the sixth and seventh cervical vertebra, and passes downwards through the lower part of the neck into the thorax. In this cavity it lies in the superior and posterior mediastina, and after piercing the diaphragm, it ends opposite the tenth or eleventh dorsal vertebra by opening into the stomach.

The length of the œsophagus is about nine or ten inches (26 centim.). It is of smaller diameter than any other division of the alimentary canal, its narrowest part being at the commencement behind the cricoid cartilage ; it is also slightly constricted in passing through the diaphragm, but, below that, widens into the stomach. It is usually flattened from before backwards, so that its lumen appears as a transverse slit (fig. 81), but occasionally it is rounded with the cavity stellate in form (fig. 82).



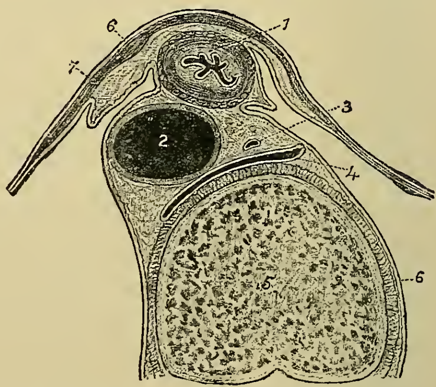


Fig. 81.—Horizontal section of trachea, œsophagus, and thyroid body. (J. S.,

1, œsophagus ; 2, cavity of trachea ; 3, cartilaginous ring of trachea ; 4, thyroid body ; 5, inferior thyroid artery ; 6, recurrent laryngeal nerve.

Fig. 82.—Horizontal section of the œsophagus and thoracic aorta at the level of the 9th dorsal vertebra. (J. S.)

1, œsophagus ; 2, thoracic aorta ; 3, thoracic duct ; 4, vena azygos major receiving a tributary from the left side ; 5, body of vertebra ; 6, pleura ; 7, diaphragm.

When empty its greatest diameter is about 20 mm., and when moderately distended, so that it acquires a cylindrical form, its diameter varies from 18 to 24 mm. It is not quite straight in its direction, but has three slight curvatures. One of these is an antero-posterior flexure, corresponding with that of the vertebral column in the neck and thorax. The other two are slight lateral curves ; for the œsophagus, commencing in the median line, inclines to the left side as it descends to the root of the neck ; thence to the fifth dorsal vertebra it gradually resumes the median position ; and finally, it deviates again to the left, at the same time coming forward towards the œsophageal opening of the diaphragm. After piercing the diaphragm, it turns abruptly towards the left side to join the stomach.

Relations.—In the lower cervical and upper dorsal region the œsophagus is applied to the anterior surface of the spine, being connected with it and with the longus colli muscle by loose areolar tissue ; opposite the middle dorsal vertebræ the thoracic duct passes obliquely upwards from right to left behind it, and then ascends on its left side ; in its lower third the œsophagus is placed in front of the aorta. In the neck the œsophagus lies close behind the trachea (projecting about a quarter of

an inch to the left of that tube), and the recurrent laryngeal nerve ascends on each side in the angle between them (see fig. 81) ; on each side is the common carotid artery and also a part of the thyroid body, but as the œsophagus inclines to the left side, it is in more immediate connection with the left carotid. In the thorax the œsophagus is successively covered in front by the lower part of the trachea, by the commencement of the left bronchus, and by the pericardium and the diaphragm. The aorta, except near the diaphragm, where the œsophagus is in front of the vessel, lies to the left, and the vena azygos major to the right and behind ; the pneumogastric nerves descend in close contact with its sides, and form a plexus around it, the left nerve proceeding gradually to the front, and the right nerve retiring behind it. In the superior mediastinum the left pleura lies close to its left side, while lower down in the posterior mediastinum the right pleura is in relation with its right side, and often extends inwards slightly behind it. Lastly, just before it pierces the diaphragm the œsophagus is in contact with both pleuræ.

STRUCTURE OF THE ŒSOPHAGUS.

The walls of the gullet are composed of three coats ; viz., an external or muscular, a middle or areolar, and an internal or mucous coat. Outside the muscular coat there is a layer of areolar tissue, with well marked elastic fibres.

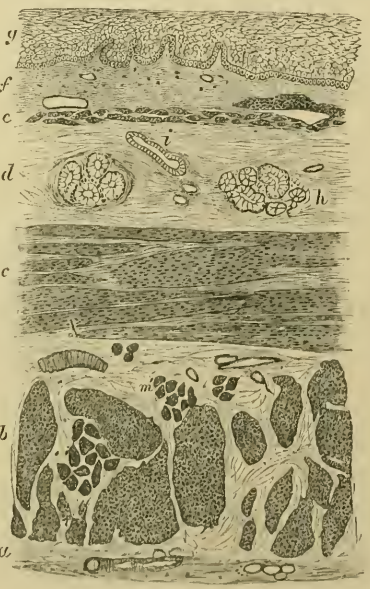


Fig. 83.—Section of the human œsophagus. (From a drawing by V. Horsley.) Moderately magnified.

The section is transverse, and from near the middle of the gullet. *a*, fibrous covering ; *b*, divided fibres of the longitudinal muscular coat ; *c*, transverse muscular fibres ; *d*, sub-mucous or areolar layer ; *e*, muscularis mucosæ ; *f*, mucous membrane, with vessels and part of a lymphoid nodule ; *g*, laminated epithelial lining ; *h*, mucous gland ; *i*, gland duct ; *m′*, striated muscular fibres cut across.

The **muscular coat** consists of an *external longitudinal layer* (seen in section in fig. 83, *b*) and an *internal* circular layer (*c*). This twofold arrangement of the muscular fibres prevails throughout the whole length of the alimentary canal ; but the two layers are here much thicker, more uniformly disposed, and more evident than in any other part, except quite at the lower end of the intestine. The external or *longitudinal* fibres are disposed at the commencement of the tube in three bands, one in front and one on each side. The lateral bands are continuous above with the inferior constrictor of the pharynx ; the anterior arises from the back of the cricoid cartilage at the prominent ridge between the posterior crico-arytenoid muscles, and its fibres spread out on each side of the gullet as they descend, soon blending with those of the lateral bundles to form a continuous layer around the tube. The direction of many of the fibres is at first slightly oblique, but towards the lower end it is more directly longitudinal. The internal or *circular* fibres are separated above by the fibres of the lateral longitudinal bands from those of the inferior constrictor of the pharynx. The rings which they form around the tube have a horizontal direction at its upper and lower part, but in the intervening space are slightly oblique. At the lower end both layers of fibres become continuous with those of the stomach.

The muscular coat of the upper end of the œsophagus is of a well marked red colour, and consists wholly of striped muscular fibres; these are gradually replaced by plain muscular fibres, so that these are almost the only ones found in the lower half of the tube. A few striped fibres may, however, be found even at the lower end, and in some animals they preponderate throughout the whole length of the tube.

The longitudinal fibres of the œsophagus are sometimes joined by a broad band of smooth muscle, passing from the left pleura, and sometimes also by another from the left bronchus. According to Cunningham, the former is almost constantly present, and the latter very frequently.

The **areolar** or **submucous** coat is placed between the muscular and mucous coats, and connects them loosely together. It exceeds the mucous membrane considerably in thickness, and in it are contained the mucous glands (fig. 83, *h*), which open on the mucous membrane.

The **mucous membrane** is of firm texture, and is paler in colour than that of the pharynx or stomach. From its loose connections its outer surface is freely movable on the muscular tunic; and under ordinary circumstances the mucous lining is thrown into longitudinal folds or rugæ, which are in mutual contact. These folds disappear on distension of the canal.

Minute papillæ (*f*) are seen upon the mucous membrane, and the whole is covered with a thick stratified scaly epithelium. In the embryo for a certain period the œsophagus is lined by columnar ciliated epithelium (Neumann), patches of which may persist even to the time of birth (Klein).

The small compound racemose or tubulo-racemose glands, named *œsophageal glands,* which are for the most part seated in the submucous tissue, are specially numerous at the lower end of the tube. A few of the smallest are situated in the substance of the mucous membrane. The cells of these glands are columnar. Their ducts are usually surrounded by collections of lymphoid tissue as they pass through the mucous membrane.

The mucous membrane is bounded next to the submucous coat by longitudinally disposed plain muscular fibres, which, imperfect above, form a continuous layer towards the lower end of the tube (*muscularis mucosæ, e*).

Duplicity of the œsophagus in part of its extent, without other abnormality, has been recorded (Blaes, quoted by Meckel).

Vessels and nerves.—The **arteries** of the œsophagus consist of a series of small vessels derived from the *inferior thyroid, descending thoracic aorta, left inferior phrenic,* and *coronary of the stomach;* these branches anastomose together. The **veins** pass to the *inferior thyroid, azygos,* and *coronary of stomach;* the submucous veins at the lower part of the œsophagus form a free communication between the portal and systemic veins, and become dilated in cases of obstruction to the circulation through the liver. The **lymphatics** go to the inferior deep cervical and posterior mediastinal glands. The **nerves** are derived from the recurrent laryngeals, vagi, and sympathetic. The blood-vessels have for the most part a longitudinal arrangement. There are separate networks for the mucous membrane, the muscularis mucosæ and the muscular coat, and the glands and fat lobules which are met with in the submucosa have each their capillary plexus. Lymphatics are found in both the submucous and mucous coats, those of the latter commencing as in the mouth and pharynx within the papillæ. A small amount of lymphoid tissue is also present, and may be accumulated into lymphoid nodules, especially in the neighbourhood of the ducts of the mucous glands. Both here and in the pharynx the alveoli of the mucous glands are invested by sinus-like lymphatic

vessels (Kidd). The nerves form a gangliated plexus between the two layers of the muscular coat, as in other parts of the alimentary canal, but it is characterised by the comparatively large size of the groups of ganglion-cells and of the cells themselves, and also by the fact that it contains, besides non-medullated fibres, a large number of medullated nerve-fibres (derived from the pneumo-gastric nerves). Each of these fibres in passing a ganglion is joined by a non-medullated fibre derived from one of the cells of the ganglion, a T-shaped junction being formed, as in the case of the nerve-fibres passing through the posterior-root ganglia. The medullated fibre then passes on and branches, and is finally distributed in terminal arborisations (motor end-organs) in the striped muscular fibres (Ranvier). The non-medullated fibres are distributed chiefly to the plain muscular tissue. There is also a gangliated plexus in the submucous tissue, from which fibres pass to the glands, and to the muscularis mucosæ, whilst others penetrate between the deeper layers of the stratified epithelium and end in an open arborisation of varicose fibrils between the cells (G. Retzius).

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THE ABDOMINAL VISCERA.

As that part of the digestive canal which is found beneath the diaphragm, and consists of the stomach and intestines, is situated within the cavity of the *abdomen*, and occupies, together with the liver and pancreas, by far the greater part of that cavity, the general topographical relations of the abdominal viscera may here be qriefly explained.

THE ABDOMEN.

The abdomen is the largest cavity in the body, and is lined by an extensive and complicated serous membrane, named the *peritoneum*. It is subdivided into two parts : an upper or larger part, *the abdomen*, properly so called ; and a lower or *pelvic* part. The limits between these portions of the cavity are marked by the brim of the true pelvis.

The abdomen proper differs from the other large cavities of the body in being bounded mainly by muscles and fasciæ (described in Vol. II., pt. 2.) instead of more or less rigid osseous walls, so that it can readily vary in its capacity according to the condition of its contained viscera. Its walls are pierced by several apertures, such as the several diaphragmatic openings for the aorta, vena cava and œsophagus, and the femoral rings and inguinal canals. In the median fibrous substance of the anterior wall lies the umbilical cicatrix. The cavity is of an irregularly oval form with the long axis directed from above downwards and having its transverse diameter usually greater than its antero-posterior. It extends under cover of the lower ribs and costal cartilages as high as the vault of the diaphragm, and below it is bounded laterally by the iliac fossæ, between which at the pelvic inlet it becomes continuous with the cavity of the pelvis. The posterior wall of the abdomen is formed by the bodies of the lumbar vertebræ with the psoas and quadratus lumborum muscles on either side. In consequence of the forward projection of the lumbar vertebræ there is a considerable hollow on either side of the spine ; so that in a horizontal section the abdominal cavity appears somewhat kidney-shaped. The walls of the pelvic cavity are mainly osseous, but its floor is formed by the integument, fat, fasciæ, and muscles, and has certain apertures which are usually closed, but can be opened for the passage of the genito-urinary products and the contents of the rectum.

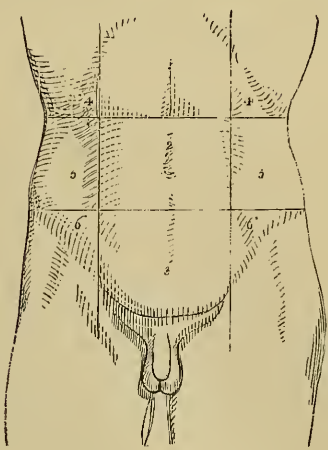

Fig. 84.—Outline of the front of the abdomen, showing the division into regions.

1, epigastric region ; 2, umbilical ; 3, hypogastric ; 4, 4, right and left hypochondriac ; 5, 5, right and left lumbar ; 6, 6, right and left iliac.

For the purpose of enabling reference to be made to the situation and condition of contained organs, the *abdomen proper* has been artificially subdivided into certain regions which are separated from one another by imaginary horizontal and sagittal planes passing through the abdomen, the edges of these planes being indicated by lines drawn upon the surface of the abdomen. By this plan the abdomen is divided into nine regions (fig. 84), the boundaries and contents of which will be described in the Appendix to this work.

THE PERITONEUM.

The **peritoneum** or serous membrane of the abdominal cavity is by far the most extensive and complicated of the serous membranes. Like the others it may be considered to form a shut sac, but in the female the two Fallopian tubes open at their free extremities into its cavity. The *parietal* layer is connected with the fasciæ lining the abdomen and pelvis by means of areolar tissue (subperitoneal); it is more firmly adherent along the middle line of the body in front, as well as to the under surface of the diaphragm. The *visceral* layer, which is thinner than the other, affords a more or less complete covering to most of the abdominal and pelvic organs. The *folds* of the peritoneum are of various kinds. Some of them constituting the *mesenteries* connect certain portions of the intestinal canal with the posterior wall of the abdomen; they are, the *mesentery* properly so called for the jejunum and ileum, the *transverse* and *sigmoid meso-colon*, and the *meso-rectum.* Other folds connected with the stomach are called *omenta*; they are the *great omentum* or *epiploon*, the *small omentum,* and the *gastro-splenic omentum.* Lastly, certain reflexions of the peritoneum from the walls of the abdomen or pelvis to viscera which are not portions of the intestinal canal are named *ligaments*; such are the ligaments of the liver, spleen, uterus, and bladder.

The further account of the peritoneum will be deferred until the abdominal viscera have been described.

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THE STOMACH.

The stomach is a dilated portion of the alimentary canal situated between the termination of the œsophagus and the commencement of the small intestine. In shape it is somewhat pyriform, with the larger end or *fundus* directed upwards and backwards on the left side, and the smaller and lower end turned to the right. It may be divided into a main or *cardiac* part, the long axis of which is directed from above downwards, forwards, and a little to the right, and a much smaller *pyloric* part, which passes nearly horizontally from left to right. Of its two open-

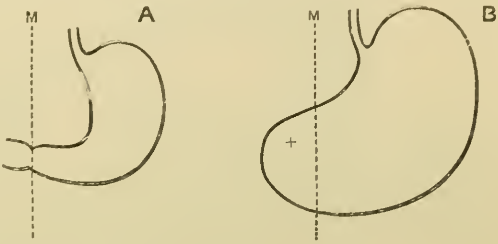


Fig. 85.—Diagrammatic outlines of the empty (A) and distended (B) stomach, seen from the front.

M dotted line represents the median plane. The + indicates position on back of organ of pyloric orifice.

ings the one, by which food enters from the œsophagus, is situated to the right of the fundus, and is named the *cardiac orifice* or *cardia*, the other, by which it passes into the duodenum, and which is placed on a lower level and more forwards and to the right, is the *pyloric orifice*, which is bounded internally by a circular constriction, sometimes also marked externally, called the *pylorus*. The stomach has two surfaces, called anterior and posterior, and two borders, termed the great and small (greater and lesser) curvatures.

Variations in position.—The stomach varies greatly in size, position, direction, and relations under normal physiological conditions, such as the condition of its muscular wall, whether relaxed or contracted, the degree of its distension, and the state of neighbouring organs.

When the stomach is empty it lies in the left hypochondrium and left half of the epigastric region, its pyloric end being situated in or near the median plane

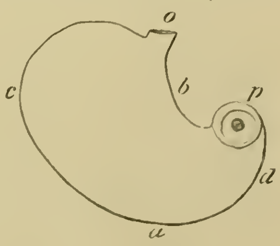


Fig. 86.—Diagrammatic outline of the stomach, as seen from behind. (His.) ¼

a, great curvature ; *b*, small curvature ; *c*, left end, great cul-de-sac, or fundus ; *d*, small cul-de-sac, or antrum pylori ; *o*, œsophageal orifice or cardia ; *p*, pyloric extremity.

under cover of the liver at the level of the last dorsal or first lumbar vertebra. The empty stomach is often described as hanging vertically, with its surfaces anterior and posterior ; but it always presents some degree of obliquity from above downwards and forwards, and not unfrequently it is more nearly horizontal than vertical, this direction being associated with a distended state of the small intestine, which pushes the lower part of the stomach upwards and forwards. Although usually flattened so as to present two surfaces and two borders, it is sometimes found contracted into a cylindrical form. This is especially the case towards the region of the pylorus, where its circular muscular fibres are best developed.

As the stomach is distended its fundus fills up the left cupola of the diaphragm, pushing the left lobe of the liver towards the right side, and tilting up the apex of the heart, while the lower part of the great curvature lies so as to come in contact with the anterior abdominal wall below the left costal wall and the liver, and not unfrequently to enter the left lumbar and umbilical regions. The distension of the stomach is also accompanied by a movement of the pylorus towards the right side,

so that this orifice of the stomach is often found under the liver close to the neck of the gall bladder, and two or three inches to the right of the median plane. This movement of the pylorus to the right side is accompanied by one of rotation, so that the orifice, which in the empty stomach is directed towards the right side, looks backwards, and the pylorus is concealed from the front by the dilated pyloric portion of the stomach. This part of the stomach moves more freely to the right

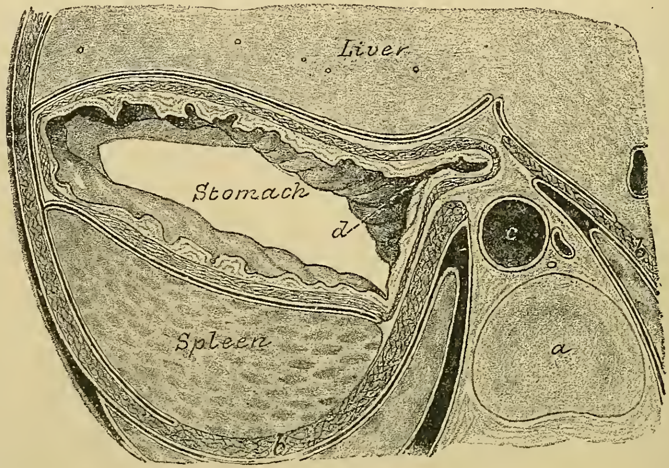


Fig. 87.—Horizontal section of abdomen of boy aged six years, at the level of the cardiac orifice. (J. S.)

a, disc between tenth and eleventh dorsal vertebræ ; *b*, diaphragm divided at the level of its œsophageal opening ; *c*, aorta ; *d*, cardiac orifice, behind this the stomach lies in direct contact with the diaphragm. The spleen is normally more completely covered with peritoneum at this level.

than the pylorus itself, so that a blind recess is gradually formed to the right of a sagittal plane passing through the pylorus. This is often called the *antrum pylori* or *small cul-de-sac.*

Cardiac Orifice.—The opening by which food enters the stomach from the œsophagus is called the *cardia*, or *cardiac orifice*. Owing to its connections with the œsophagus and diaphragm, the cardiac orifice is the most fixed part of the stomach. It is situated at the level of the body of the 10th or 11th dorsal vertebra, in front and to the left side of the aorta, and behind a notch in the posterior surface of the left lobe of the liver. It lies, on an average, about 4 or 5 inches posterior to the interval between the ensiform process and the inner end of the 7th left costal cartilage. It appears from the researches of Braune and v. Gubaroff that the cardiac orifice may have a valvular action independent of its muscular fibres. Thus, after dividing the thorax horizontally some distance above the diaphragm, and filling the stomach with fluid by injecting from the cut end of the œsophagus, they found that the gastric contents were retained, although the œsophagus was not ligatured. After piercing the diaphragm the œsophagus turns somewhat abruptly to the left side to open into the stomach, and it is probable that when the stomach is distended this bend is increased so as to obstruct the return of its contents into the œsophagus.

Pylorus.—From what has already been said regarding the movements of the stomach, it is evident that the position of the pylorus in relation to the anterior surface of the abdomen must vary considerably. As a rule, both in the empty and in the distended state of the stomach it is overlapped in front by the liver, which thus separates it from the abdominal wall. When the stomach is empty the pylorus is in, or close to, the median plane, and an inch or so below the ensiform

process; but, as already mentioned, it is found two or three inches to the right of the median plane when the stomach is distended. Occasionally the pylorus lies directly against the abdominal wall, just below the liver. The position of the pyloric orifice can be recognized by a slight constriction on the outer surface of the organ, and also by a thickening of the wall, which can be readily felt by taking it between the thumb and fore-finger. The closure of this opening is produced by the contraction of the circular muscular fibres, which are well developed in this situation, and form a distinct projection towards the orifice. This contraction at the pylorus is sometimes associated with a similar condition of the muscular fibres of the stomach for an inch or more from the pylorus, while the rest of the stomach is dilated. Viewed from its duodenal side the closed pylorus presents some resemblance to the external os uteri, but the opening is stellate or rounded. When the stomach and duodenum are distended and dried the opening of the pylorus is usually circular, about half an inch in diameter, and bounded by an annular projection. When distended and hardened with alcohol the annular fibres at the orifice appear in section as a sharply marked band of considerable thickness, producing a sharp prominence of the mucous membrane into the interior.

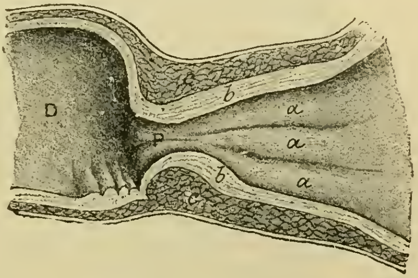


Fig. 88. — Section through pyloric part of stomach and commencement of duodenum, from a specimen hardened in situ. (J. S.) $\frac{1}{1}$

a, *a*, *a*, longitudinal folds of the mucous membrane in pyloric part of stomach; *b*, section of mucous membrane; *c*, circular muscular fibres of stomach, the longitudinal fibres are just visible to the naked eye as a narrow line external to the circular fibres; D, duodenum; P, pyloric orifice.

Borders.—The borders of the stomach are termed the small and great curvatures. They give attachment to folds of peritoneum, between the layers of which bloodvessels and lymphatics reach the organ. The small curvature is readily recognized by its giving attachment to the *small* or *gastro-hepatic omentum*. It passes from the cardiac orifice at first downwards and a little to the left, and then turns somewhat abruptly to the right, to end at the upper border of the pylorus. Near this opening it often has one or two depressions with intervening convex prominences. The great curvature is four or five times as long as the small, and consists of an upper, a left, and a lower portion. Traced from the œsophageal orifice it will be found to pass to the left, forming an upwardly directed convexity, where it encircles the upper part of the fundus. On the left side of the fundus it first passes nearly straight downwards, and then turns to the right to end at the pylorus. The lower part of the great curvature forms a convexity directed downwards; it gives attachment to the *great* or *gastro-colic omentum*, and usually has the transverse colon just below it. Towards the pylorus its general curve may be interrupted by one or two depressions.

Surfaces.—The *surfaces* of the stomach are usually termed *anterior* and *posterior*, but as already mentioned, the anterior surface looks more or less upwards and the posterior downwards. Usually flattened when the stomach is empty, they become convex on distension, so that in this condition the distinction between the borders and surfaces of the organ is ill-defined. Behind the cardiac orifice there is a small area of the stomach which is uncovered by peritoneum, and lies in direct contact with the diaphragm (see fig. 87), and also often with the upper part of the left suprarenal capsule. The reflection of the peritoneum at the boundaries of this area from the stomach to the diaphragm is called the *gastro-phrenic ligament*. With this exception both surfaces of the stomach are entirely covered by peritoneum. On the

posterior aspect near the left part of the great curvature the gastro-splenic omentum is attached.

The anterior surface of the stomach is in contact with the under surface of the left lobe of the liver and the diaphragm ; also, when distended, with the anterior

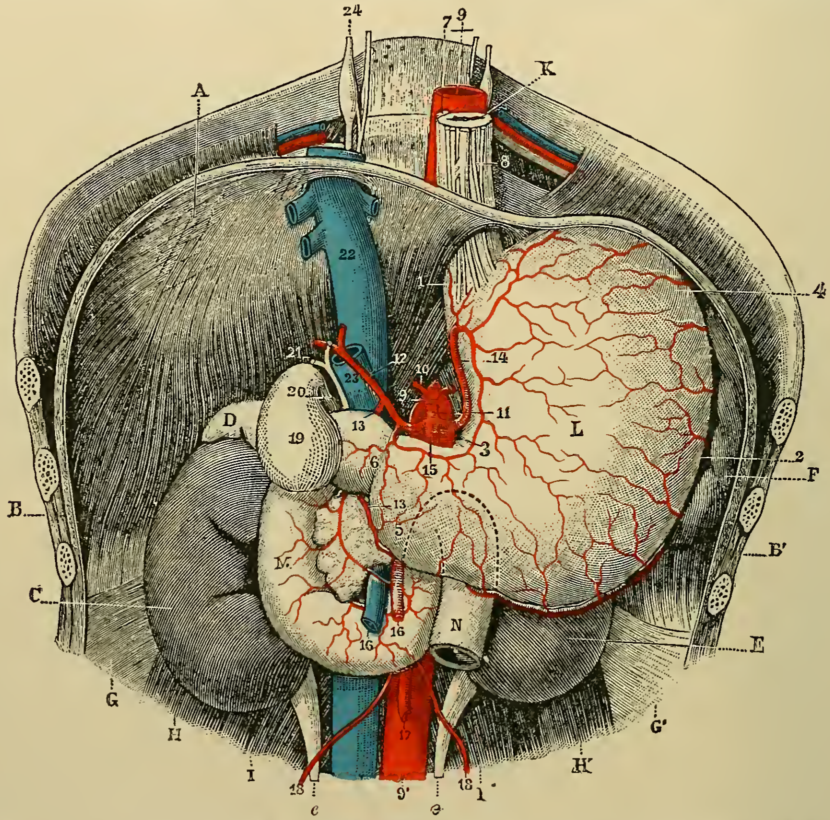


Fig. 89.—View of the stomach in situ after removal of the liver and the intestine (except the duodenum and commencement of jejunum). (Testut.)

A, diaphragm ; B, B′, thoracico-abdominal parietes ; C, right kidney with *c*, its ureter ; D, right suprarenal capsule ; E, left kidney with *e*, its ureter ; F, spleen ; G, G′, aponeuroses of the transverse abdominal muscles ; H, right quadratus lumborum muscle ; H′, left ditto ; I, right psoas magnus and parvus muscles ; I′, left ditto ; K, œsophagus ; L, stomach ; M, duodenum ; N, jejunum ; the position of the duodeno-jejunal junction behind the stomach is indicated by dotted lines. 1, termination of œsophagus ; 2, great curvature of stomach ; 3, small curvature ; 4, fundus ; 5, antrum pylori ; 6, pyloric end ; 7, right vagus nerve ; 8, left ditto ; 9, thoracic aorta ; 9′, abdominal aorta ; 10, inferior phrenic artery ; 11, cœliac axis ; 12, hepatic artery ; 13, right gastro-epiploic ; 14, coronary artery ; 15, splenic artery ; 16, 16′, superior mesenteric artery and vein ; 17, inferior mesenteric artery ; 18, spermatic arteries ; 19, gall bladder ; 20, cystic duct ; 21, hepatic duct ; 22, inferior vena cava ; 23, portal vein ; 24, sympathetic cord.

abdominal wall and the quadrate lobe of the liver. Occasionally the transverse colon is found in front of the stomach.

Posteriorly the stomach is in relation with the diaphragm, the spleen, the left suprarenal capsule, the upper end of the left kidney, the pancreas, and the splenic flexure of the colon. It is separated from the duodeno-jejunal junction and some convolutions of the small intestine by the transverse mesocolon. The pyloric portion of the stomach exhibits a tendency to sacculation owing to constrictions due to local contractions of the muscular fibres. One or more of these constrictions are often found on both the great and the small curvatures, but they seldom extend all round the stomach, and can generally be obliterated by full distension. Occasionally, how-

ever, a constriction occurs which is of a more permanent character, and partially divides the stomach into two parts (hour-glass form).

Dimensions.—These vary greatly in different subjects, and also according to the state of distension of the organ. When moderately filled its length, measured from the top of the fundus to the lowest part of the great curvature, is about 10 to 12 inches, and its diameter at the widest part from 4 to 5 inches. The distance

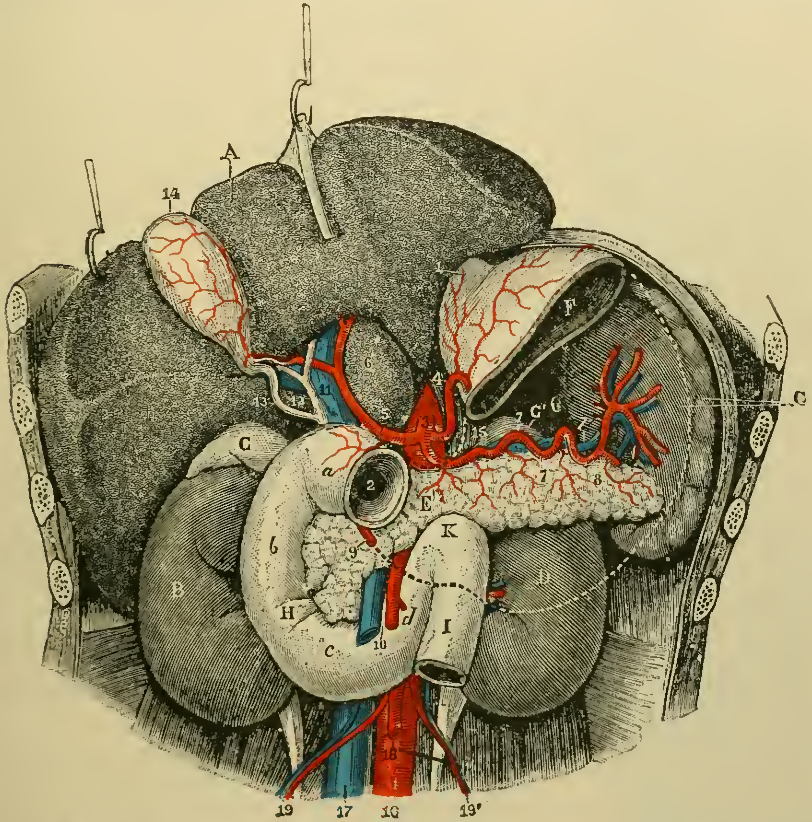


Fig. 90.—View of the liver, duodenum, pancreas, spleen, &c. The greater part of the stomach has been removed to show its posterior relations ; its position is indicated by a dotted outline. (Testut.)

A, inferior surface of liver ; B, right kidney ; C, C′, right and left suprarenal capsules : D, left kidney ; E, pancreas ; F, upper part of stomach ; G, spleen : H, duodenum with *a*, *b*, *c*, *d*, its four portions ; I, jejunum ; K, duodeno-jejunal junction ; 1, lower end of œsophagus ; 2, pyloric orifice ; 3, cœliac axis ; 4, coronary artery ; 5, hepatic artery ; 6, lobus Spigelii of liver ; 7, 7′, splenic vessels ; 8, left gastro-epiploic ; 9, right gastro-epiploic ; 10, superior mesenteric vessels ; 11, portal vein ; 12, hepatic duct ; 13, cystic duct ; 14, gall bladder : 15, left crus of diaphragm ; 16, aorta ; 17, inferior vena cava ; 18, inferior mesenteric vessels ; 19, 19′, spermatic vessels.

between its two orifices varies from 3 to 6 inches. It weighs, when freed from other parts, about $4\frac{1}{2}$ ounces in the male and somewhat less in the female (Glendinning) (about 200 grammes, Duroy). Its capacity is, on an average, about 5 pints (Brinton) (2 to 3 litres).

Variations according to age.—In the new-born child the stomach is small and usually empty. Its general form and position are very similar to that of the empty and contracted stomach in the adult, but in consequence of the large size of the left lobe of the liver the whole of its anterior surface is covered by this organ. When it becomes distended the movement of its pyloric portion towards the right side is probably impeded by the large size of the liver.

STRUCTURE OF THE STOMACH.

The stomach has four coats, named, in order from without inwards, the serous, muscular, areolar or submucous, and mucous tunics (fig. 91).

The **external** or **serous coat** (*s*), derived from the peritoneum, is a thin, smooth, transparent, and elastic membrane, which closely covers the entire viscus, excepting along its two curvatures, and a small area near the cardiac end. Along the line of these curvatures the attachment is looser, leaving an interval occupied by the larger blood-vessels.

The second, or **muscular coat,** is composed of plain muscular tissue, forming

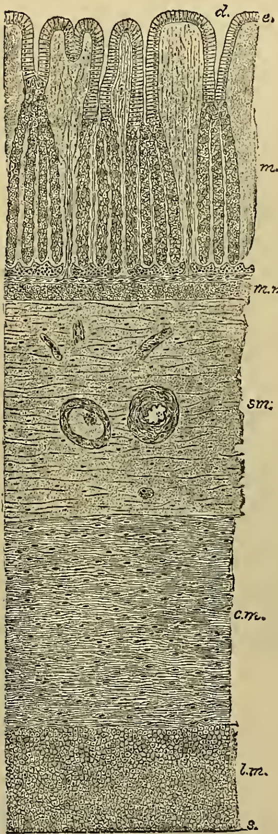


Fig. 91.—Section through the coats of the stomach. Diagrammatic. (Mall.)

m., mucous membrane ; *e.*, epithelium ; *d.*, orifice of gland duct ; *m.m.*, muscularis mucosæ ; *sm.*, submucous coat ; *c.m.*, circular muscular layer ; *l.m.*, longitudinal muscular layer ; *s.*, serous coat.

three sets of fibres, disposed in layers, and named, from their direction, the longitudinal, the circular, and the oblique fibres.

The first or outermost layer consists of the *longitudinal* fibres (fig. 91, *l.m.*, fig. 92, A), which are in direct continuity with those of the œsophagus. They spread out in a radiating manner from the cardiac orifice, and are found in greatest abundance along the curvatures, especially the lesser one. On the anterior and posterior surfaces they are very thinly scattered, or scarcely to be found, but towards the pylorus are well marked and form a thick uniform layer, which, passing over the pylorus, becomes continuous with the longitudinal fibres of the duodenum.

The second set consists of the *circular* fibres (fig. 91, *c.m.*, fig. 92, B) which form a complete layer over the whole extent of the stomach. They commence by small and thinly scattered rings at the extremity of the great cul-de-sac, describe larger and larger circles as they surround the body of the stomach at right angles to its curved axis, and towards the pyloric end again form smaller rings, and at the same time become much thicker and stronger than at any other point. At the pylorus itself they are gathered into a thick bundle (fig. 88, in section), which forms, within a circular fold of mucous membrane, a well-marked projection—the *pyloric sphincter.* Some of the circular fibres appear to be continued from those of the œsophagus, spreading from its right side.

The innermost muscular layer is incomplete, and consists of the *oblique* fibres (fig. 92, C). These are continuous with the circular fibres of the gullet, on the left of the cardiac orifice, where they form a considerable stratum ; from that place they descend obliquely upon the anterior and posterior surfaces of the stomach, where they spread out from one another, and, taking the direction of the circular fibres, gradually disappear on the greater curvature.

The **submucous coat** of the stomach is a distinct layer connecting the muscular and mucous coats (fig. 91, *s.m.*). It consists of areolar tissue, in which occasional

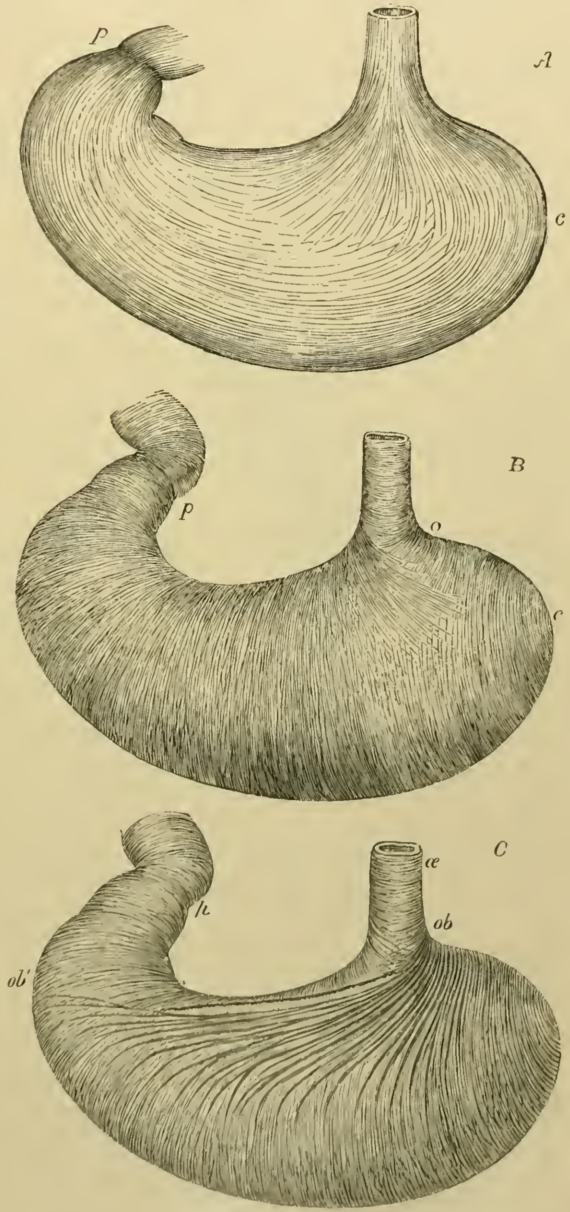
fat-cells may be found; and it is the seat of division and passage of the blood-vessels.

The **internal coat** or **mucous membrane** is a smooth, soft, rather thick and pulpy membrane, which in the fresh state has generally a somewhat pink hue owing

Fig. 92.—Sketch of the arrangement of the fibres in the muscular coat of the stomach. (Allen Thomson.) $\frac{1}{3}$

A, external layer of longitudinal fibres, as seen from the outside; B, middle layer of circular fibres as seen on removing the longitudinal layer; C, oblique fibres exposed by removing some of the fibres of the circular layer, the cut edges of which are seen below the small curvature.

c, the cardiac end; *p*, the pyloric end; in A are shown the stronger longitudinal fibres passing along the small and large curvatures, and all round the pyloric end, and radiating from the end of the gullet over the front (and back) of the stomach; in B, the nearly uniform layer of circular fibres, in two sets crossing each other very obliquely at *o*, and at the cardiac end becoming concentric to the centre of the great cul-de-sac; in C, the oblique fibres, *ob*, *ob′*, which form a continuation of the circular fibres of the gullet (*œ*), and spread from the left side of the cardia, gradually merging into the deeper circular fibres, with which finally they entirely blend.



to the blood in its capillary vessels. In infancy the vascular redness is more marked.

The mucous membrane is thickest in the pyloric region, and thinnest in the great cul-de-sac. It always becomes thinner in old age.

It is connected with the muscular coat by means of the intervening submucous layer so loosely as to allow of considerable movement or displacement. In consequence of this, and of the want of elasticity of the mucous membrane, the internal surface of the stomach, when that organ is in an empty or contracted state, is thrown into numerous convoluted ridges, *rugæ*, which are produced by the wrinkling of the mucous, together with the areolar coat, and are entirely obliterated by distension of the

stomach. These folds are most evident along the greater curvature, and have a general longitudinal direction.

On examining the gastric mucous membrane closely with the aid of a simple lens, it is seen to be marked throughout, but more plainly towards the pyloric extremity, with small depressions which have a polygonal figure, and vary from about 0·12 to 0·25 mm. across, being larger and more oblong near the pylorus. They are the enlarged mouths or ducts of the tubular glands with which the mucous membrane of the stomach is beset (fig. 91).

Towards the pyloric region of the stomach these depressions are larger and deeper, and their margins are elevated into pointed processes, which resemble, especially in vertical section, rudimentary villi, but the perfect forms of those appendages exist only in the small intestine, and make their appearance in the duodenum, immediately beyond the pylorus (fig. 91).

Epithelium of the surface.—The thick stratified epithelium of the œsophagus passes abruptly at the cardia into a simple layer of columnar epithelium, which completely covers the inner surface of the stomach, and extends to a variable distance into the mouths of the gastric glands. The transition of the stratified into the columnar epithelium occurs quite suddenly, the lowermost columnar cells of the stratified epithelium passing into the single columnar layer of the gastric surface, and all the other layers of the stratified epithelium ceasing abruptly.

The epithelial cells of the surface of the stomach differ in some respects from the columnar epithelium of the intestine. They are more elongated in form, and

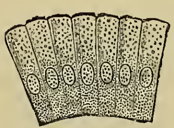


Fig. 93.—Epithelium of the surface of the stomach examined fresh (Heidenhain). Highly magnified.

in inactive conditions of the organ they exhibit two parts, the attached end of the cell being granular, the free part—that turned towards the cavity of the organ—occupied by a clear, muco-albuminous substance (mucigen). Moreover, there is no striated border as in the intestinal cells. The clear substance swells and is discharged from the cell during digestion, leaving empty the part of the cell which contained it, and a similar change is produced by water and various other reagents. Between the smaller ends of the columnar cells, small, round, or oval cells occur, sometimes in small nests (Watney).

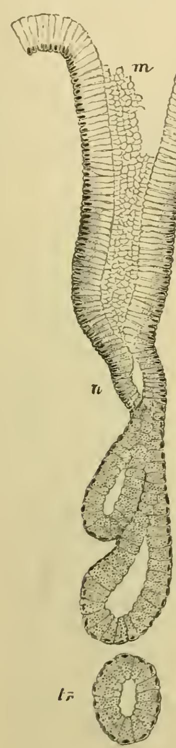
Gastric glands.—As was first shown by Sprott Boyd, the surface of the stomach within the depressions above mentioned is dotted with small round apertures, which are the openings of minute glandular tubules, placed perpendicularly to the surface. On making a vertical section of the membrane, and submitting it to microscopic examination, it is seen to consist almost entirely of these small tubules, arranged parallel with each other (fig. 91). Each mouth or duct, together with the tubules which open into it, constitutes a *gastric gland.*

Some of the glands may be simple, consisting of a single tubule throughout, but most are cleft into two or three tubules, or even, by the branching of these, eventually into six or eight. The glands have externally a basement membrane, composed of flattened cells joined edge to edge, and with processes which on the one side join the retiform tissue of the mucous membrane, and on the other side, more delicate, extend in amongst and support the enclosed epithelium cells.

Two kinds of glands are distinguished, which differ from one another both in the character of the enclosed cells, and, it is believed, in the nature of their secretion. Those of the one kind (fig .94) are simpler in structure than the others, and being found most numerously in the pyloric region, they have been named *pyloric glands.* These are distinguished by the large size and depth of the gland-mouth as compared with the tubules which open into it, and by the character of

the epithelium lining the tubules. The mouth of the gland is lined throughout by an epithelium which is continuous with and similar to the columnar epithelium which covers the general surface of the stomach. But in the tubules of the gland the lining cells are shorter and more cubical, and are uniformly finely granular throughout; moreover, they are filled with secretion of a different nature from that of the surface epithelium.

Amongst the cells of these glands there are occasionally found others which are characterised by becoming darkly stained with osmic acid (Nussbaum). They have



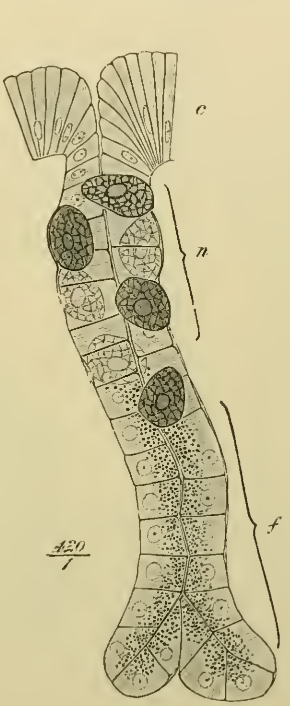


Fig. 94.—A PYLORIC GLAND, FROM A SECTION OF THE DOG'S STOMACH. (Ebstein.)
m, mouth; *n*, neck; *tr*, a deep portion of a tubule cut transversely.

Fig. 95.—A CARDIAC GLAND OF SIMPLE FORM, FROM THE BAT'S STOMACH. (Langley.)
Osmic acid preparation. *c*, columnar epithelium of the surface; *n*, neck of the gland with central and parietal cells; *f*, base or fundus, occupied only by principal or central cells, which exhibit granules accumulated towards the lumen of the gland.

been supposed to represent the parietal cells of the cardiac glands (see below), but this is probably not the case.

In the glands of the second kind (figs. 91, 95, 96)—which may be termed, from the portion of the stomach where they occur most numerously, the *cardiac glands* * (*fundus glands* of Heidenhain, *oxyntic* † *glands* of Langley)—the mouth, or part lined with epithelium like that of the surface, is comparatively short, and into it open two, three, or more tubules, which are lined throughout and almost filled with short columnar or polyhedral cells; these cells are in most respects similar to the

* This name has, however, been also applied to certain glands situated close to the cardia which contain *no* parietal cells. These glands were first described in the Kangaroo (Schäfer and Williams, Proc. Zool. Soc., London, Jan. 18, 1876), and they have since been shown to occur in man and all mammals (Edelmann, Inaug. Diss., Rostock, 1889). See also Oppel, Vergleich. mikr. Anat. der Wirbelthiere, Jena, 1896).

† From ὀξύς, acid; since they contain the cells which are believed to produce the acid of the gastric secretion.

secreting cells of the pyloric glands, but are much more coarsely granular. They were termed by Heidenhain the *principal cells* of the glands; they are also known as the *central cells.* Between these cells and the basement membrane of the tubule other cells of a different nature are interpolated in the cardiac glands. These are the *superadded, parietal,* or *oxyntic cells.* They were long thought to be the only cells of the cardiac glands, and were on that account known as "peptic cells," a term which must now be entirely discarded.

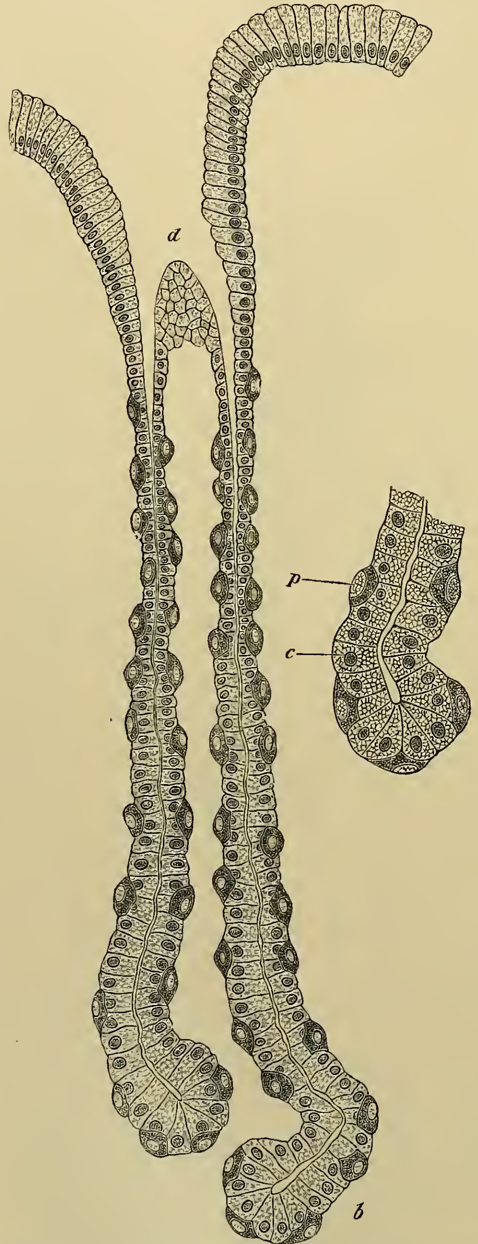


Fig. 96.—A cardiac gland from the dog's stomach. (Klein and Noble Smiths.) Highly magnified.

d, duct or mouth of the gland; *b,* base or fundus of one of its tubules. On the right the base of a tubule more highly magnified; *c,* central cell; *p,* parietal cell.

Fig. 97.—A gastric gland: the lumen shown by chromate of silver. (E. Müller.)

The cells are not represented, but the extension of the lumen into the network surrounding the parietal cells is well shown.

The parietal cells are rather more closely arranged in the neck of the gland than elsewhere. They usually cease abruptly at the upper part of the neck, but occasional cells may be found under the columnar epithelium of the mouth or even of the general surface. In the human stomach they are only absent from the glands which are quite near the pylorus.

In some animals (porpoise, pig) the parietal cells lie each in a special pit formed by basement membrane, and communicating with the rest of the gland only by a narrow orifice. In the glandular stomach of birds they line secondary tubules which lead out of the main tubule, this alone being lined by principal cells. In the frog and other amphibia the cardiac glands have only parietal or oxyntic cells, the principal cells being altogether absent, but glands containing cells which are similar in appearance and function to the principal cells of the stomach are found in the œsophagus.

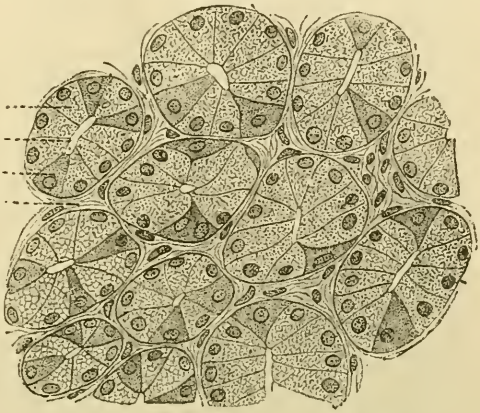


Fig. 98. — Cross-section of cardiac glands from the human stomach, showing the condition of the cells during fasting. (Böhm and v. Davidoff.) $\frac{500}{1}$

c, central cell ; *l*, lumen of gland ; *p*, parietal cell ; *t*, connective tissue between glands.

The parietal cells have a finely granular appearance in the fresh condition, but in the gland hardened in alcohol are much darker and more granular-looking. This appearance is due, according to Klein, not to the presence of actual granules within the cells, but to the existence of a close and uniform intracellular network (fig. 96). They are more readily stained than the principal cells.

Fine intercellular passages extend from the lumen of the gastric glands between the lining epithelium cells, and in the case of the cardiac glands these passages pass to the parietal cells and invest them with a pericellular network (E. Müller) (fig. 97).

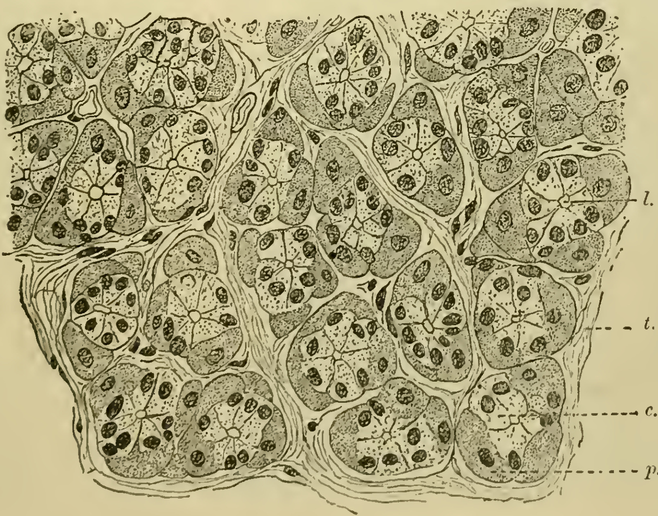


Fig. 99.—Cross-section of cardiac glands from the human stomach, showing the condition of the cells during digestion. (Böhm and v. Davidoff.) $\frac{500}{1}$

(References as in Fig. 98.)

The cells of the gastric glands undergo changes during the functional activity of the organ which are strictly comparable to the changes that have been described in the cells of the serous salivary glands. The principal cells of the cardiac glands are enlarged and almost fill the lumen of the tubule in the intervals of digestion, and in this so-called "resting" or "loaded" condition they are in some animals granular throughout, while in others there is a small outer zone clear of granules. But they become smaller and distinctly differentiated into two zones during activity, some of the granules becoming dissolved and discharged with the secretion,

and the rest tending towards the lumen of the gland so as to leave the outer half or third of the cell clear of granules (fig. 95). After digestion has ceased the outer parts of the cells become again partially or wholly occupied by granules (Langley). On the other hand the parietal cells of the cardiac glands are smaller during fasting, and are then angular in form (fig. 98). During digestion, on the other hand, they become enlarged and more spheroidal, bulging out the tunica propria of the glands (fig. 99).

Heidenhain first showed that both the central cells and the parietal cells undergo a change of size during digestion, becoming at first enlarged and subsequently shrinking to less than their volume during rest. The changes occur later in the parietal than in the central cells.

The secreting cells of the pyloric glands undergo changes which are similar to those of the central cells of the cardiac glands (Ebstein).

Between the glands and at their base the mucous membrane consists of delicate connective tissue with retiform lymphoid tissue in small amount.

A thin layer of plain muscular tissue (*muscularis mucosæ*, fig. 91, *m.m.*) bounds the mucous membrane externally, separating it from the submucous tissue. It consists of more than one stratum (an outer longitudinal and an inner circular), and is better marked in some animals than in man. Offsets pass from it between the gastric glands towards the surface of the mucous membrane.

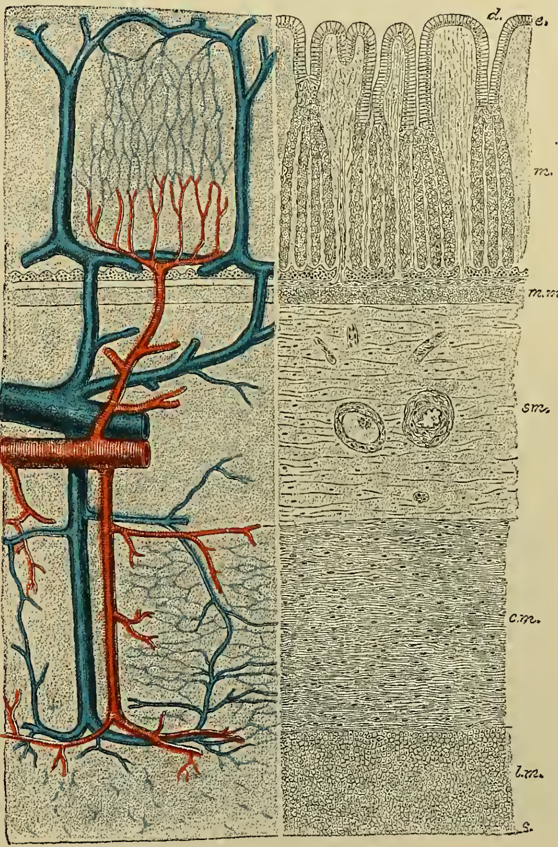


Fig. 100.—Section through the coats of the stomach to show the arrangement of the principal blood-vessels. (Mall.)

On the right side of the figure the glandular and muscular elements are shown ; on the left only the blood-vessels. It will be seen that the principal vessels are in the submucous tissue, and that from these, branches are distributed to the mucous membrane and to the muscular coat.

Lymphoid Follicles.—The stomachs of young persons sometimes present a mamillated aspect, due to little elevations of the surface, which are produced by local accumulations of lymphoid tissue, and somewhat resemble the solitary follicles of the intestine in appearance. The lymphoid accumulations in question are situated amongst the glands, and do not extend into the submucous tissue ; they are not so distinctly circumscribed as those of the intestine, but fade off into the surrounding retiform tissue. They are most numerous near the junction of the stomach and small intestine (Watney). They vary in development in different individuals, and are sometimes not to be found at all.

Vessels and Nerves.—The stomach is a highly vascular organ. Its **arterial** branches, derived from all three divisions of the *cœliac axis*, reach the stomach

between the folds of the peritoneum, and form, by anastomosing together, two principal arterial arches, which are placed along its two curvatures. Their branches pass through the muscular coat (to which in passing they give off some arterioles) and divide into smaller vessels in the submucous areolar tunic, where they also freely anastomose, and whence they are distributed to the mucous membrane and to the muscular layers. The arterial branches (fig. 101, *a*) which enter the mucous membrane, pass between the tubuli, ramifying freely in a radial manner; here they form a plexus (*d*) of fine capillaries upon the walls of the tubules; and from this plexus larger vessels pass into a coarser capillary network around the mouths of the glands. The **veins**, fewer in number than the arteries, arise from the latter network, and take an almost straight course (*c*, *c*) through the mucous membrane between the glands and join to form a plexus of larger vessels near the bases of the glands. From this plexus branches pass off, which, after piercing the muscularis mucosæ and forming a wide venous plexus in the submucous tissue, return the

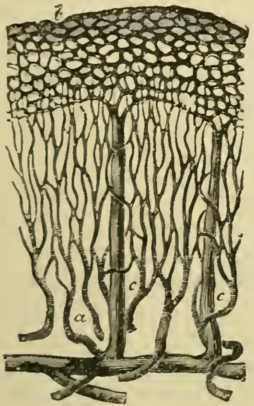


Fig. 101.—Plan of the blood-vessels of the mucous membrane of the stomach. (Modified from Brinton.)

a, small arteries passing to break up into the fine capillary network, *d*, between the glands; *b*, coarser capillary network around the mouths of the glands; *c*, *c*, veins passing vertically downwards from the superficial network; *e*, larger vessels in the submucosa.

Fig. 102.—Lymphatics of the human gastric mucous membrane, injected (from Lovén).

The tubules are only faintly indicated; *a*, muscularis mucosæ; *b*, plexus of fine vessels at base of glands; *c*, plexus of larger valved lymphatics in submucosa.

residual blood into the splenic and superior mesenteric veins, and also directly into the vena portæ. These veins, as well as other tributaries of the vena porta, have a particularly well-marked muscular coat, and contain numerous valves (Hochstetter).

The **lymphatics** are very numerous. As shown by Lovén, they arise in the mucous membrane (fig. 102) by a dense network of lacunar spaces, situated between and amongst the gland-tubuli, which, as well as the blood-vessels, in many parts they enclose in sinus-like dilatations. Near the surface of the membrane the lymph is collected into vessels which form loops or possess dilated extremities: these vessels are less superficial than the blood capillaries. At the deeper part of the mucous membrane the interglandular lymphatics pass into a plexus of fine vessels (*b*), immediately underlying the tubular glands; then piercing the muscularis mucosæ (*a*), they form a coarser, more deeply-seated network (*c*) in the

submucous coat, the vessels of this network being provided with valves. Thence efferent lymphatics proceed, and, piercing the muscular coats, follow the direction of the blood-vessels beneath the peritoneal investment, and traverse lymphatic glands found along the two curvatures of the stomach.

The *nerves*, which are large, consist of the terminal branches of the two pneumogastric nerves, belonging to the cerebro-spinal system, and of offsets from the sympathetic system, derived from the solar plexus. The left pneumo-gastric nerve

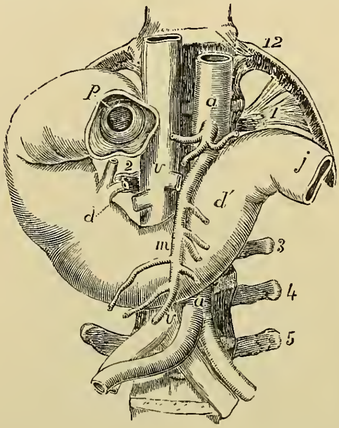


Fig. 103.—View of the pylorus and duodenum from before. The stomach and duodenum have been distended and hardened in spirit, and the greater part of the stomach then cut away. (Slightly altered from Luschka.) $\frac{1}{4}$

12, the twelfth dorsal vertebra and rib ; 1, 3, 4, 5, transverse processes of the first, third, fourth, and fifth left lumbar vertebræ ; 2, that of the second on the right side ; *a*, *a*, the abdominal aorta above the cœliac axis and also near the bifurcation ; *m*, superior mesenteric artery ; *v*, *v*, the vena cava above the renal veins and near the bifurcation ; *p*, placed on the first part of the duodenum, points to the pyloric orifice seen from the side next the stomach, of which a small part is left connected with the intestine ; *d*, on the descending part of the duodenum, indicates the termination of the common bile-duct and the pancreatic duct ; *d′*, the ascending part of the duodenum ; *j*, the commencement of the jejunum. (This is represented as drawn over to the left, instead of curving forward, as is actually the case.)

descends on the front, and the right upon the back of the stomach, and both nerves are here composed almost entirely of non-medullated nerve-fibres. Numerous small ganglia have been found by Remak and others on both the pneumo-gastric and sympathetic twigs. The nerves form gangliated plexuses (like the plexuses of Auerbach and Meissner) of the intestine, both between the layers of the muscular coat and in the submucous coat. From these plexuses nerve-fibrils proceed to the muscular tissue and to the mucous membrane.

The Pylorus.—While there is no special apparatus at the cardiac orifice of the stomach for closing the passage from the œsophagus, the opening at the pyloric

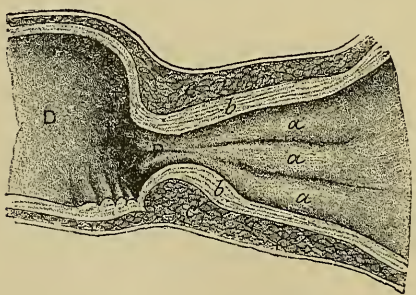


Fig. 104.—Section through pyloric part of stomach and commencement of duodenum, from a specimen hardened in situ. (J. S.) $\frac{1}{1}$

a, *a*, *a*, longitudinal folds of the mucous membrane in pyloric part of stomach ; *b*, section of mucous membrane ; *c*, circular muscular fibres of stomach : the longitudinal fibres are just visible to the naked eye as a narrow line external to the circular fibres ; D, duodenum ; P, pyloric orifice.

end, leading from the stomach into the duodenum, is provided with a sphincter muscle. On looking into the pyloric end of a distended stomach, the mucous membrane is seen projecting in the form of a circular fold, called the *pylorus*, leaving a correspondingly narrow opening. Within this fold are circular muscular fibres, belonging to the general system of circular fibres of the alimentary canal, which are here collected in the form of a strong band, whilst the longitudinal muscular fibres and the peritoneal coat pass over the pyloric fold to the duodenum, and do not enter into the formation of the sphincter (fig. 104, *p* ; fig. 105). Externally the pylorus may be easily felt, like a thickened ring, at the right end of the stomach, where also a

slight external constriction is visible. Internally its opening is usually circular, and even when the stomach is artificially distended after death it measures less than

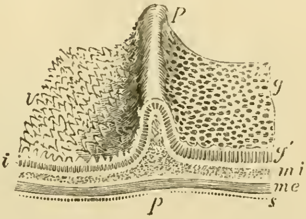


Fig. 105.—Diagrammatic view in perspective of a portion of the coats of the stomach and duodenum, including the pylorus. (Allen Thomson.)

g, the inner surface of the gastric mucous membrane; *g'*, section of the mucous membrane with the pyloric gastric glands; *v*, the villous surface of the mucous membrane of the duodenum; *i*, section of the same with the intestinal glands or crypts of Lieberkühn; *p p*, the ridge of the pyloric ring, with a section of its component parts; *mi*, deep or circular layer of muscular fibres: these are seen in the section to form the pyloric sphincter; *me*, external or longitudinal layer of muscular fibres; *s*, the serous covering.

half an inch (12 mm.) across, so that it is the narrowest part of the whole alimentary canal.

Occasionally the orifice is oval, and it is often placed a little to one side. Sometimes the circular rim is imperfect, and there are found instead two crescentic folds, placed one above and the other below the passage (Huschke); and, lastly, there is occasionally but one such crescentic fold.

When the sphincter is contracted the longitudinal fibres covering it are bowed inwards, and these, if they contract at the same time that the sphincter muscle relaxes, will tend to dilate the orifice.

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THE SMALL INTESTINE.

The small intestine commences at the pylorus, and, after many convolutions, terminates in the large intestine. It measures, on an average, about 22 feet in length in the adult, and becomes gradually narrower from its upper to its lower end. Its convolutions occupy the middle and lower parts of the abdomen, and also frequently descend into the pelvis.

The small intestine is divided into three portions, which have received different names. The first ten or twelve inches immediately succeeding to the stomach, and comprising the widest and most fixed part of the tube, is called the *duodenum.* This part is further distinguished by its close relation to the head of the pancreas, and by the absence of a mesentery. The remainder, which is arbitrarily divided into an upper two-fifths called the *jejunum,* and a lower three-fifths called the *ileum,* is very convoluted and movable, being connected with the posterior abdominal wall by a long and extensive fold of peritoneum called the mesentery, and by numerous blood-vessels and nerves. Although there is no distinct line of demarcation between the jejunum and the ileum, yet the portion of the small intestine included under these two names gradually undergoes certain changes in structure and appearance from above downwards, so that the upper end of the jejunum can readily be distinguished from the lower part of the ileum.

STRUCTURE OF THE SMALL INTESTINE.

The small intestine, like the stomach, is composed of four coats, viz., the serous or peritoneal, muscular, areolar, and mucous.

The external or **serous coat** almost entirely surrounds the intestinal tube in the whole extent of the jejunum and ileum, leaving only a narrow interval behind, where it passes off and becomes continuous with the two layers of the mesentery. The line at which this takes place is named the *attached* or *mesenteric border* of the intestine. The duodenum, on the other hand, is but partially covered by the peritoneum.

The **muscular coat** consists of two layers of fibres ; an outer longitudinal, and an inner or circular set. The *longitudinal* fibres constitute an entire but comparatively thin layer, and are most obvious along the free border of the intestine. The *circular* layer is thicker and more distinct.

The muscular tunic becomes gradually thinner towards the lower part of the small intestine. It is pale in colour, and is composed of plain muscular tissue, the cells of which are of considerable length. The progressive contraction of these fibres, commencing in any part of the intestine, and advancing in a downward direction, produces the peculiar *vermicular* or *peristaltic* movement by which the contents are forced onwards through the canal. In the narrowing of the tube the circular fibres are mainly concerned, the longitudinal fibres tending to produce dilatation (Exner) ; and those found along the free border of the intestine may have the effect of straightening or unfolding its successive convolutions. There is a gangliated plexus of nerve-fibres and a network of lymphatic vessels between the two muscular layers.

The **submucous coat** of the small intestine is a layer of areolar tissue of a loose texture, which is connected more firmly with the mucous than with the muscular coat. Within it the blood-vessels ramify before passing to the mucous membrane, and there is a gangliated plexus of nerve-fibres and a network of large lymphatic vessels.

The internal coat or **mucous membrane** is characterised by the finely flocculent or shaggy appearance of its inner surface, resembling the pile upon velvet. This appear-

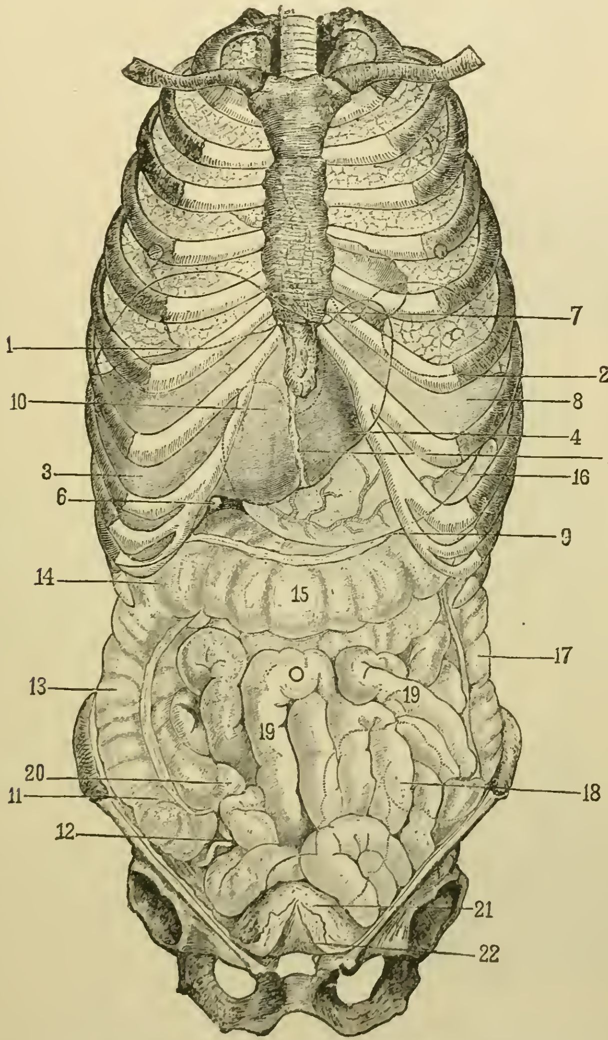


Fig. 106.—Diagram showing the position of the thoracic and abdominal organs. (Rauber after Luschka.)

1, Lower border of the right lung; 2, the same of the left lung; 3, liver, right lobe; 4, liver, left lobe; 5, suspensory ligament of the liver; 6, fundus of gall-bladder; 7, cardia of stomach; 8, fundus of stomach; 9, lower border of stomach; 10, position of pylorus; 11, cæcum; 12, vermiform appendix; 13, ascending colon; 14, right flexure of colon; 15, transverse colon; 16, position of left flexure of colon; 17, descending colon; 18, portion of sigmoid colon, concealed by 19, convolutions of the small intestine; 20, termination of ileum, ascending from left to right; 21, bladder, distended, partly covered by peritoneum; 22, the part of the bladder which is not covered by peritoneum.

ance is due to the surface being thickly covered with minute processes named *villi*. It is one of the most vascular membranes in the body, and is naturally of a reddish

colour in the upper part of the small intestine, but is paler, and at the same time thinner, towards the lower end. It is lined with columnar epithelium throughout its whole extent, and next to the submucous coat is bounded by a layer of plain muscular tissue (*muscularis mucosæ*); between this and the epithelium the substance of the membrane, apart from the tubular glands which will be afterwards described, consists mainly of retiform tissue which supports the blood-vessels, nerves, and lymphatics (lacteals), and encloses in its meshes numerous lymph-corpuscles.

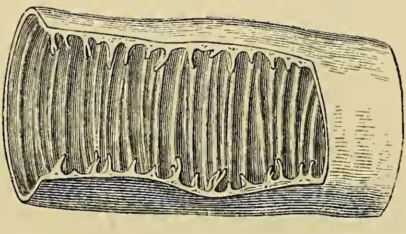


Fig. 107.—Portion of small intestine distended with alcohol and laid open to show the valvulæ conniventes. (Brinton.)

Valvulæ conniventes.—The mucous membrane, in addition to small effaceable folds or rugæ, possesses also permanent folds, which cannot be obliterated, even when the tube is forcibly distended. These permanent folds are the *valvulæ conniventes* or *valves of Kerkring.* They are crescentic projections of the mucous membrane, placed transversely to the axis of the bowel and following one another closely. The majority of the folds do not extend more than about one-half or two-thirds round the interior of the tube, but it has been shown by Brooks and Kazzander that some form complete circles, and others spirals. The spiral forms may occur singly or in groups of two or three. They generally extend a little more than once round the bowel, but in rare cases may go round two or three times. At their highest point they project inwards for about a third of an inch. Some of the valvulæ conniventes are bifurcated at one or both ends, and others terminate abruptly. Each consists of a fold of mucous membrane, that is, of two layers placed back to back, and united together by submucous areolar tissue. They contain no part of the circular or longitudinal muscular coats. Being extensions of the mucous membrane, they serve to increase the absorbent surface to which the food is exposed.

Fig. 108.—Small portion of the surface of the mucous membrane of the small intestine. (Rauber.) $\frac{30}{1}$

1, mouths of crypts of Lieberkühn; 2, villi.

The valvulæ conniventes are not uniformly distributed over the various parts of the small intestine. There are none quite at the commencement of the duodenum; a short distance from the pylorus they begin to appear; beyond the point at which the bile and pancreatic juice are poured into the duodenum they are very large, regularly crescentic in form, and placed so near to each other that the intervals between them are not greater than the breadth of one of the valves; they continue thus through the rest of the duodenum and along the upper half of the jejunum; below that point they begin to get smaller and farther apart, and finally, towards the middle or lower end of the ileum, having gradually become more irregular and indistinct, sometimes even acquiring a very oblique direction, they altogether disappear.

The **villi**, peculiar to the small intestine, and giving to its internal surface

the velvety appearance already spoken of, are small processes of the mucous membrane, which are closely set on every part of

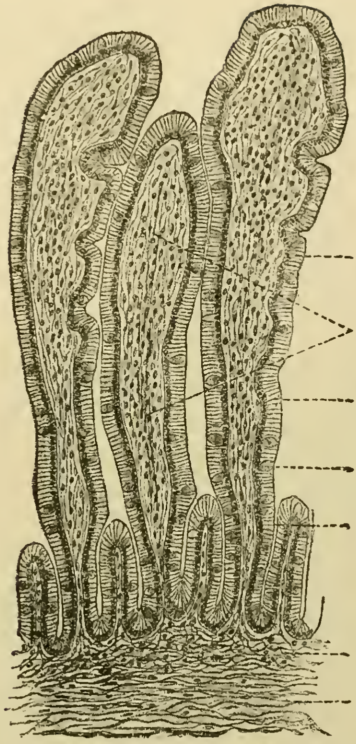


Fig. 109.—Section of the human intestinal mucous membrane (? child), showing three villi with crypts of Lieberkühn. (Böhm and v. Davidoff.) $\frac{88}{1}$

the inner surface over the valvulæ conniventes, as well as between them.

Their length varies from 0·5 mm. to 0·7 mm., or sometimes more. They are largest and most numerous in the duodenum and jejunum, and become gradually smaller, and fewer in number in the ileum. According to Rauber, they are short and leaf-shaped in the duodenum, and as the gut is followed downwards they become gradually longer and thinner, so that they are tongue-shaped in the jejunum, and filiform in the ileum. Occasionally two or three are connected together at their base. In the upper part of the small intestine there are from 10 to 18 villi in a square millimeter, and in the ileum from 8 to 14 in the same space. This would give about 4 millions altogether (Krause).

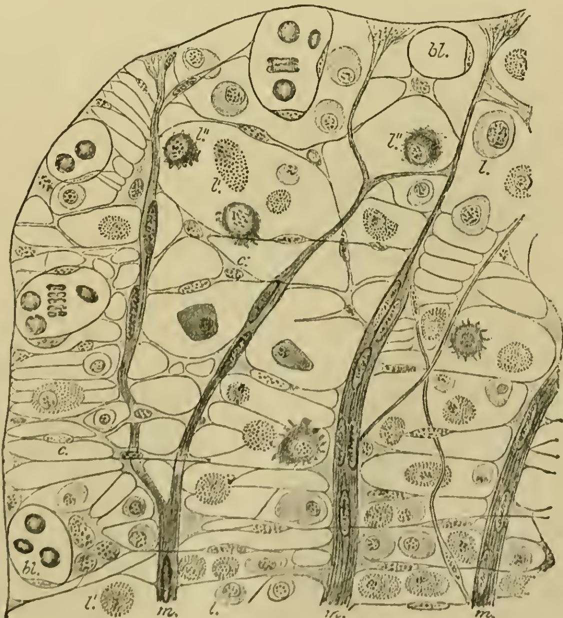


Fig. 110.—Part of a section through a villus of the dog, highly magnified. (R. Heidenhain.)

m, *m*, muscular fibres ; *l*, *l'*, *l''*, lymph-corpuscles ; *bl*, blood-vessels ; *c*, branched connective tissue corpuscles, covering the reticular fibres. The epithelium of the villus is not represented.

Chaput describes the villi as being so closely arranged as to be separated merely by narrow clefts into which the crypts of Lieberkühn open. This may be the case in the empty condition of the intestine, but when it is distended they are necessarily more separated from one another as usually described.

A villus consists of a prolongation of the proper mucous membrane. It is covered by columnar epithelium (fig. 109), and en-

closes a network of blood-vessels, one or more lymphatic vessels (lacteals), and a few longitudinal plain muscular fibre-cells, these being all supported and held together by retiform lymphoid tissue. Under the epithelium is a basement membrane composed of flattened cells, which on the one hand are connected with the branched cells of the retiform tissue, and on the other hand send processes between the epithelium-cells. Nervous fibrils penetrate into the villi from the plexus of Meissner, and form arborizations throughout their whole substance (fig. 130, p. 99). Each villus receives, as a rule, one small *arterial* twig, which runs from the submucous coat through the mus-

Fig. 111.—Magnified view of the blood-vessels of the intestinal villi. (Sharpey.)

The drawing was taken from a preparation injected by Lieberkühn, and shows, belonging to each villus, a small artery and vein with the intermediate capillary network.

cularis mucosæ to the base of the villus, and then up the centre to near the middle of the villus, where it begins to break up into a number of capillaries (fig. 111). These form near the surface, beneath the epithelium and limiting membrane, a fine capillary network, from which the blood is returned for the most part by one or two venules, which in man commence near the tip of the villus, and pass down to its base to join the venous plexus of the mucous membrane, whence the blood is conveyed to the large veins of the submucosa. The general arrangement of the vascular supply of the villi varies considerably in different animals.

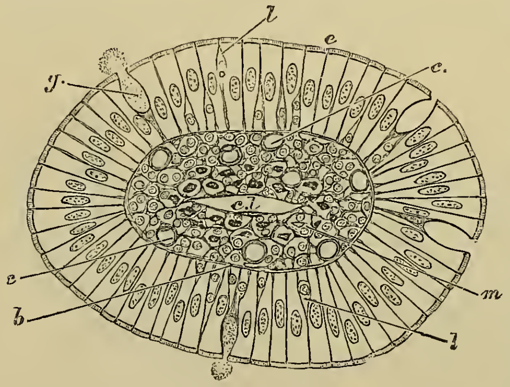


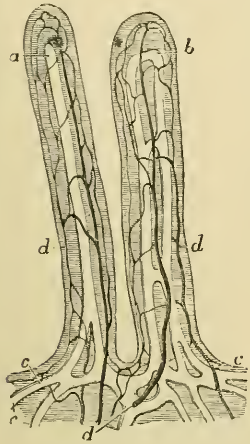
Fig. 112.—Cross section of a villus of the cat's intestine. (Highly magnified.) (E. A. S.)

e, columnar epithelium ; *g*, goblet cell, its mucus is seen partly exuded ; *l*, lymph-corpuscles between the epithelium cells ; *b*, basement membrane ; *c*, blood-capillaries ; *m*, section of plain muscular fibres ; *c.l.*, central lacteal.

The lacteal lies in the centre of the villus (figs. 112, 113, 114), and is in the smaller villi usually a single vessel, with a closed and somewhat expanded extremity, and of considerably larger diameter than the capillaries of the blood-vessels around. According to the observations of Teichmann, there are never more than two intercommunicating lacteals in a single villus in the human subject (fig. 113, *b*) ; but both he and Frey found a copious network in the villi of the sheep. Like the lymphatics elsewhere, the lacteals in the villi are bounded by a delicate layer of flattened epithelial cells. These are connected with the branched cells of the tissue of the villus (fig 110, *c*), and these again with the flattened cells which form the basement membrane ; from the latter, prolongations extend between the epithelium-cells towards the surface.

The muscular tissue within the villus was discovered by Brücke ; it consists of a thin stratum of plain fibre-cells disposed longitudinally around the lacteal ; on being stimulated in animals they produce an obvious retraction of the villus.

This muscular tissue is a prolongation from the muscularis mucosæ. The fibre-cells at the sides and towards the end of the villus pass from the lacteal to be



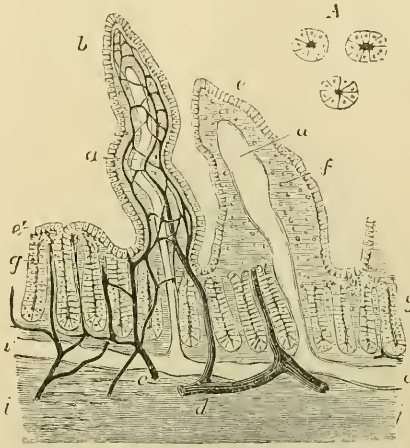


Fig. 113.—Injected lacteal vessels in two villi of the human intestine. 100 diameters. (Teichmann.)

The lacteals are represented as filled with white substance and the blood-vessels with dark. *a*, *b*, the lacteal vessels, single in one villus and double in the other ; *c*, the horizontal lacteal vessels with which those of the villi communicate ; *d*, the blood-vessels, consisting of small arteries and veins with capillary network between.

Fig. 114.—Vertical section of the intestinal mucous membrane of the rabbit. (Slightly altered from Frey.) $\frac{150}{1}$

Two villi are represented, in one of which the dilated lacteal alone is shown, in the other the blood-vessels and lacteal are both seen injected, the lacteal white, the blood-vessels dark : *a*, the lacteal vessels of the villi ; *a'*, horizontal lacteal, which they join ; *b*, capillary blood-vessels in one of the villi ; *c*, small artery ; *d*, vein ; *e*, the epithelium covering the villi ; *g*, tubular glands or crypts of Lieberkühn, some divided down the middle, others cut more irregularly ; *i*, the submucous layer.

A, cross section of three tubular glands more highly magnified.

attached to the basement membrane (fig. 110, *m. m.*) ; usually their attachment to this is forked, a connective tissue corpuscle filling up the interval (Watney).

Fig. 115.—Columnar epithelium cells of the rabbit's intestine. (E. A. S.)

A. Two cells isolated after maceration in very weak chromic acid. They are much vacuolated, and one of them (2) has a fat-globule attached near its end ; the striated border (*str.*) is well seen, and the bright disk separating this from the cell-protoplasm ; *n*, nucleus with intranuclear network ; *a*, a thinned out wing-like projection of the cell which probably fitted between two adjacent cells.

B. A row of columnar cells from an intestinal villus of the rabbit. *str*, striated border ; *w*, smaller cells of the nature of lymph-corpuscles, between the epithelium cells.

Columnar epithelium cells (figs. 109, 112, 115) cover not only the villi but also the rest of the surface of the intestine, and extend into the tubular glands. Their general characters have already been described under the head of "Epithelium" (see Vol. I., Part 2, pp. 199, 200).

They are set upon the surface of the basement membrane often by a somewhat flattened extremity. There is never any continuity between their attached extremity and the branched corpuscles of the retiform tissue of the villus, such as has often been supposed to exist; on the contrary, the epithelium separates with the greatest readiness from the subjacent tissue, and almost always with a simple truncated extremity, sometimes pitted but never much branched. Between

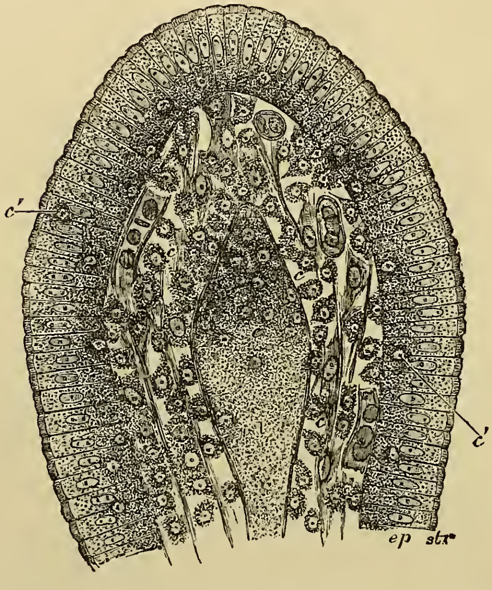


Fig. 116.—Section of part of a rat's villus during absorption of fat. (E. A. S.) Osmic acid preparation. Highly magnified.

ep, epithelium, filled with fatty particles; *str*, striated free border; *c*, lymph-corpuscles in the tissue of the villus, containing fatty particles; *c′*, others between the epithelium cells; *l*, central lacteal, containing chyle and disintegrating leucocytes.

the epithelium cells are leucocytes in variable number, but most numerous in the lower part of the intestine and near the lymphoid follicles. They often show indications of division by karyokinesis. They may lie free in small (lymph) spaces between the columnar cells.

There is frequently a well-marked layer of granular eosinophil cells immediately below the epithelium of the villi (Hardy).

Amongst the ordinary epithelium cells are others (fig. 112, *g*), the outer half of which is filled with mucigen, and in some this has become discharged as mucus from the cell, and the free end is ruptured (*goblet cells*, see Vol. I., Part 2, p. 200). The number of cells containing mucus varies much in different animals, and perhaps, under different conditions, in the same animal. There are comparatively few in the glands of the small intestine. The epithelial cells are in all probability the primary agents in promoting the absorption of the food materials from the interior of the gut, and the seat of the retrograde processes of

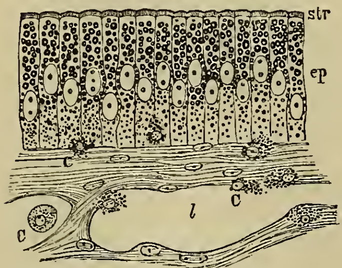


Fig. 117.—Section of frog's intestine during absorption of fat. (E. A. S.) Osmic acid preparation. Highly magnified.

ep, epithelium; *str*, its striated border; *l*, lacteal; *c*, *c*, lymph-corpuscles containing fine fatty particles. The fatty particles in the epithelium cells are coarse in the peripheral and fine in the central zone of each cell.

metabolism which the products of digestion undergo during absorption. Most food materials cannot be traced in microscopic specimens, but fatty substances, from their property of becoming stained with osmic acid, can be to some extent followed. The examination of such specimens taken during digestion of a meal containing fat shows the epithelium cells turbid with oil-droplets in their interior; and in some animals (frog, rat), at a subsequent stage amœboid cells within the tissue of the villus appear pervaded with similar but finer fatty particles, and eventually the central lacteal becomes filled with these. It is probable that the amœboid lymph-corpuscles

which are found so abundantly within the tissue of the villus, and even amongst the epithelium-cells of the surface, play an important part in the transference of such particles from the epithelium-cells to the lacteal, for at certain stages of fat absorption they contain abundant fatty particles, and the large amount of lymphoid tissue in the lower end of the small intestine seems to be related to a greater power of absorption in that part of the gut. In the transference of carbon particles in the lungs from the interior of the alveoli to the lymphatics, which at least in part is due to the activity of amœboid cells, we have an analogous process.

In other animals (dogs) the absorption of fat appears to occur in a fluid form, and here we see darkly stained streaks extending from the inter-epithelial spaces to the borders of the central lacteal.

It has been denied by Heidenhain that the lymphoid cells of the intestine contain fatty particles during fat absorption : he states that the particles within them which are stained black by osmic acid are not fatty but albuminous, being insoluble in ether. This is, however,

Fig. 118.—Section of the mucous membrane of the small intestine across the crypts of Lieberkühn. (Rauber.) $\frac{200}{1}$

(The blood-vessels had been injected in this preparation.)

Fig. 119.—Lymphoid or retiform tissue of the intestinal mucous membrane of the sheep (from Frey). Magnified 400 diameters.

Cross section of a small fragment of the mucous membrane, including one entire crypt of Lieberkühn and parts of several others : *a*, cavity of the tubular glands or crypts ; *b*, one of the lining epithelial cells ; *c*, the lymphoid or retiform spaces, of which some are empty, and others occupied by lymph-cells as at *d*.

not correct. Many of the particles which the lymph-cells contain during fat absorption unquestionably dissolve in ether and other solvents of fat, although there are some cells which contain particles which are undissolved by those re-agents. These may be of an albuminous nature, or they may still be fatty, but so modified by the action of the osmic acid as to have been rendered insoluble in ordinary fat solvents. In the frog, where absorption proceeds more slowly, and can be more easily traced, no fat is to be seen anywhere but in the epithelium cells, in the leucocytes, and in the lacteals. In the guinea-pig also, as Heidenhain has himself shown, amœboid cells take up the whole of the absorbed fat, after it has traversed the epithelium. In other animals absorption may take place so rapidly that the absorbed fat, after being finely divided and modified in the epithelium cells, may be set free between them without all being immediately taken up by leucocytes. Eventually, however, most of it appears to be removed by these cells. The agency of the epithelium cells in fat absorption has been denied (Watney, Zawarykin), but on entirely insufficient grounds, for the absorbed fat is very easily shown within those cells.

Glands.—Two kinds of small secreting glands open on the inner surface of the intestine, viz., the crypts of Lieberkühn, and Brunner's glands, the last being peculiar to the duodenum. In addition to these, numerous lymphoid nodules are found, which are either scattered and isolated (solitary glands) or collected into patches (Peyer's glands).

The **crypts of Lieberkühn**, the smallest but most numerous of these glandular structures, are found in every part of the small intestine, opening on the surface

between the villi (figs. 109, 114, 118, 119). They consist of minute tubes, closed at their attached extremity, which is slightly enlarged, and placed more or less perpendicularly to the surface, upon which they open sometimes two or three together. The crypts of Lieberkühn vary in length from 0·2 to 0·3 mm., and their diameter is about 0·04 mm. They are longest in the duodenum. The walls of the tubes are formed of a basement membrane, lined with a columnar epithelium (fig. 119), the deepest cells of which—those, that is to say, at the fundus of the glands, are in some animals filled with granules (Paneth). Goblet-cells occur here and there amongst the ordinary cells.

Although it is usually believed that mucus-secreting or goblet cells may be formed from any of the columnar epithelium cells of the intestine, it would appear from the observations of Bizzozero, that the granules of the cells of the gland-fundus are mucigen-granules, and that it is these cells which give rise to the goblet cells not only of the glands themselves but also of the surface epithelium of the mucous membrane and villi. In this process they become gradually shifted in position, their place being taken by other cells formed by a process of cell-division at the base of the glands. While this seems to be the mode of production of the goblet or mucus-producing cells, the ordinary columnar cells appear to be formed near the mouths of the glands, where karyokinetic figures are common (they are very rare on the villi themselves), and to become shifted along the villi as any of the columnar cells of those organs become destroyed.

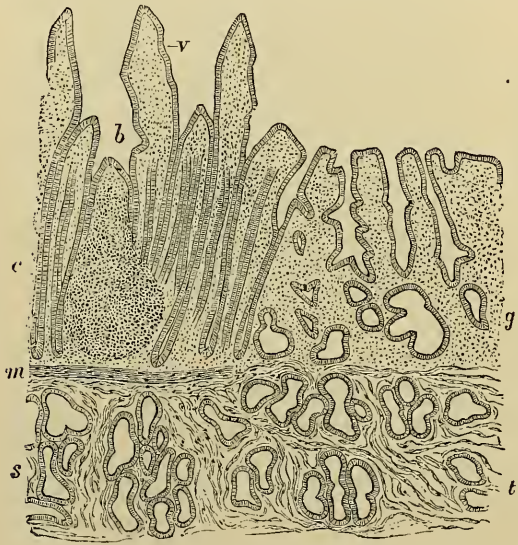


Fig. 120.—Section through the commencement of the duodenum at the pylorus. (Klein.)

v, villi; *b*, apex of a lymphoid nodule; *c*, crypts of Lieberkühn; *m*, muscularis mucosæ; *s*, secreting tubes of Brunner's glands; *d*, ducts of pyloric glands of stomach; *g*, tubes of these glands cut across in mucous membrane; *t*, deeper lying tubes situated in submucous tissue, and corresponding with Brunner's glands of the intestine.

Brunner's glands are small compound acino-tubular glands, which exist in the duodenum, where they are most numerous at the upper end, in general occupying thickly a space extending from one to two inches beyond the pylorus. A few of them are said also to be found quite at the commencement of the jejunum. They are imbedded in the submucous coat, and may be exposed by dissecting off the muscular coat from the outside of the intestine. They may extend partly into the mucous membrane between the crypts of Lieberkühn. In structure they somewhat resemble the small glands which are found in various parts of the lining membrane of the mouth and elsewhere, each consisting of a number of tubular alveoli, connected by the terminal ramifications of the duct, which latter penetrates the muscularis mucosæ, and opens upon the inner surface of the intestine. The ducts open either between the crypts of Lieberkühn or in some cases into the bases of the crypts (Schaffer). In sections through the pylorus the glands of Brunner appear like direct continuations of the pyloric glands of the stomach (Watney), which they closely resemble in structure, but they are somewhat more complicated and more deeply seated.

The **solitary glands** are soft, white, rounded, and slightly prominent bodies 0·6 mm. to 3 mm. in diameter, which are found scattered over the mucous

membrane in every part of the small intestine. They are found as well at the mesenteric as at the free border, both between and upon the valvulæ conniventes, and are rather more numerous in the lower portion of the bowel. These so-called

Fig. 121.—Section of a solitary gland of the small intestine. (Cadiat.)

c, *c*, villi, partially deprived of their epithelium ; *d*, crypts of Lieberkühn ; *a*, solitary gland composed of retiform lymphoid tissue, which has become partly broken away in preparing the section ; *b*, epithelium covering the apex or cupola of the follicle ; *e*, *e*, muscularis mucosæ ; *f*, submucous coat.

glands are in structure similar to the lymphoid nodules of various parts already described, consisting of clumps of dense retiform tissue, the meshes of which are closely packed with lymph-corpuscles, and pervaded by fine capillaries. They are here and there united at the sides with the surrounding lymphoid tissue, but are at most points distinctly marked off from it, partly owing to the fact that their supporting retiform tissue becomes closer and finer, partly owing to their being surrounded by a rich plexus of lymphatic vessels ; or they even hang, as it were, into a lymphatic

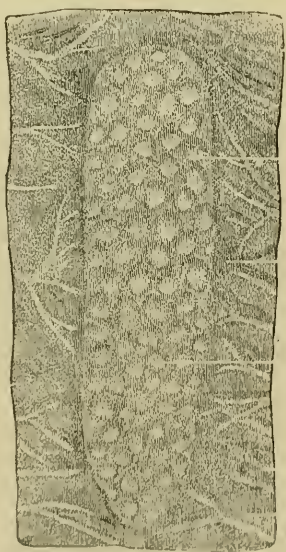


Fig. 122.—A small patch of Peyer's glands from the ileum. Slightly magnified (Boehm).

(or lacteal) sinus, which may entirely surround the nodule, except next the inner surface of the intestine. The epithelium over the nodule often has a large number of lymph-corpuscles between the epithelial cells. The base of the nodule or follicle is situated in the submucous tissue ; but it extends upwards, through the muscularis mucosæ, into the mucous membrane, causing a bulging of this towards the interior of the gut (as in fig. 124, *d d*). The prominent part of the follicle sometimes has villi upon it, and, placed around very irregularly, are seen the mouths of the crypts of Lieberkühn.

The **agminated glands or glands of Peyer** (who described them in 1677) are groups or patches of lymphoid nodules. The groups have an oblong figure (fig. 122), and vary from half an inch to two or even four inches in length, and from half an inch to about an inch in width (12 mm. to 120 mm. long and 12 mm. to 25 mm. broad). They are placed lengthways in the intestine at that part of the tube most distant from the mesentery ; and hence, to obtain the best view of them, the bowel should be opened by an incision along its attached border.

The lymphoid nodules which by their aggregation make up a Peyer's patch are in almost all respects similar to the solitary glands above described. As a rule, their

surface is free from villi, and the crypts of Lieberkühn are collected in circles around them. Fine blood-vessels are distributed abundantly on the exterior of the

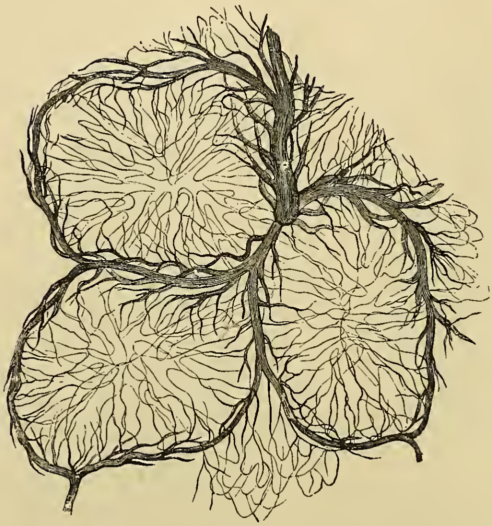


Fig. 123.—Portion of an injected Peyer's patch (from Kölliker). Magnified.

The drawing was taken from a preparation made by Frey of the intestine of the rabbit. It represents the fine capillary network spreading from the surrounding blood-vessels into the interior of three lymphoid nodules.

follicles, and give off still finer capillary branches, which, supported by the retiform tissue, are disposed principally in lines converging to the centre (fig. 123).

The lacteal plexuses, which are abundant in the whole extent of the intestine, are especially rich where they surround the follicles of Peyer's glands (fig. 124), often forming sinuses around them, as in the case of the solitary follicles above described.

In all, from twenty to thirty of these oblong patches may in general be found; but in young persons dying in health as many as forty-five have been observed.

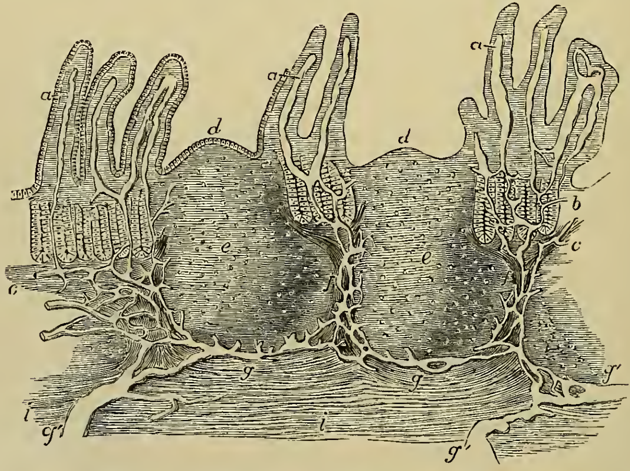


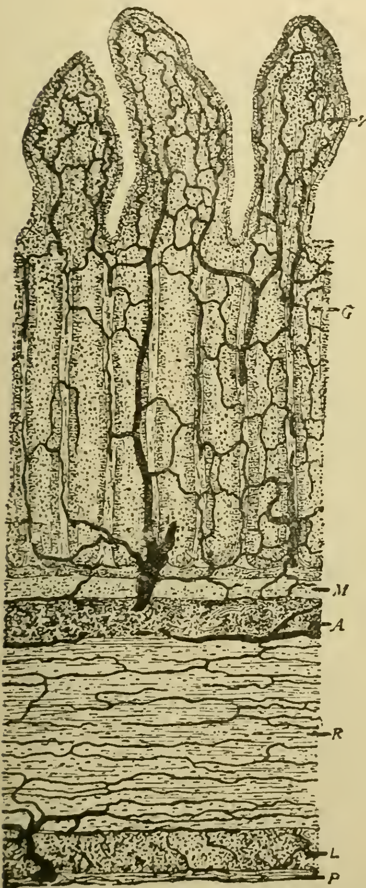
Fig. 124.—Vertical section of a portion of a patch of peyer's glands, with the lacteal vessels injected (after Frey). 32 diameters.

The specimen is from the lower part of the ileum: *a*, villi, with their lacteals left white; *b*, some of the tubular glands; *c*, the muscular layer of the mucous membrane; *d*, cupola or projecting part of the nodule; *e*, central part; *f*, the reticulated lacteal vessels occupying the lymphoid tissue between the nodules, joined above by the lacteals from the villi and mucous surface, and passing below into *g*, the reticulated lacteals under the follicles, which again pass into the large efferent lacteals, *g'*; *i*, part of the muscular coat.

They are larger and placed at shorter distances from each other in the lower part of the ileum; but in the upper portion of that intestine and in the lower end of the jejunum the patches occur less frequently, become smaller, and are of a nearly circular form; they may, however, be discovered occasionally in the lower portion of

the duodenum. Still smaller irregularly shaped clusters of these follicles are sometimes found scattered throughout the intestine.

The glands of Peyer are best marked in the young subject. After middle life they become less obvious, and disappear almost completely in advanced age, their remains being often indicated by dark colouration of the mucous membrane.



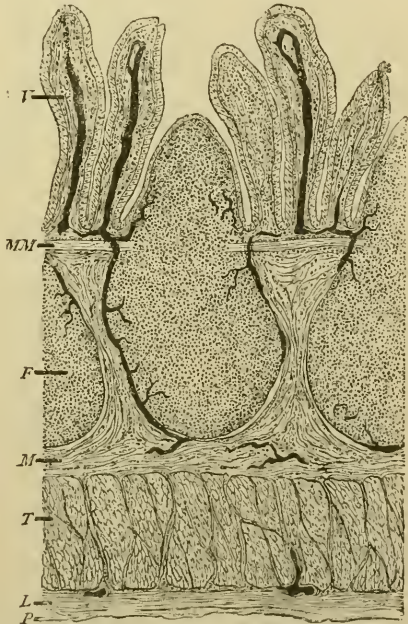


Fig. 125.—Section of small intestine with blood-vessels injected. (Heitzmann.)

V, villi; *G*, glands; *M*, muscularis mucosæ; *A*, areolar coat; *R*, circular, and *L*, longitudinal muscular layers; *P*, peritoneal coat.

Fig. 126.—Section through part of a Peyer's patch showing the lymphatics injected. (Modified from Heitzmann.)

V, villi; *MM*, muscularis mucosæ; *F*, lymphoid follicles; *M*, mucous membrane; *T*, circular, and *L*, longitudinal layers of the muscular coat; *P*, peritoneal layer. The crypts of Lieberkuhn are seen in this section.

Vessels and Nerves of the small intestine.—The branches of the mesenteric artery, having reached the attached border of the intestine, pass round its sides, dividing into numerous ramifications, and frequently anastomosing at its free border. Most of the larger branches run immediately beneath the serous coat; they then pierce the muscular coat, supplying it with a few vessels as they pass, and ramify in the submucous areolar layer, so as to form a close network. From this smaller vessels pass into the mucous coat. Some of these are the arteries of the villi, already described. Others pass to the mucous membrane and supply a network of capillaries surrounding its glands. Other branches again pass into the muscular coat from the vessels of the submucosa. The fine capillaries of the muscular coat are arranged in two layers of oblong meshes, which correspond in

direction with the longitudinal and circular muscular fibres. The veins accompany the arteries, with which they correspond in general distribution.

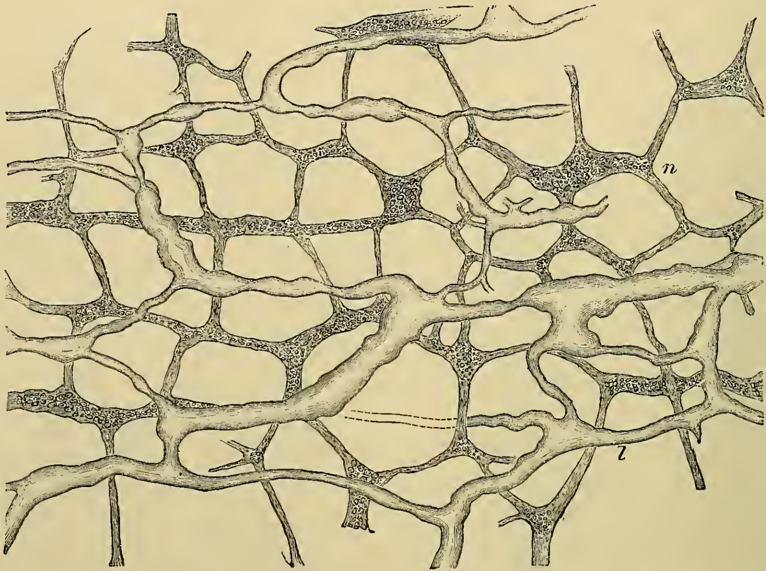


Fig. 127.—Lymphatic plexus (*l*) and nervous plexus (*n*) in the muscular coat of the intestine (Auerbach).

The **lymphatics** of the intestine (lacteals) may be conveniently distinguished as those of the mucous membrane and those of the muscular coat. Those of the

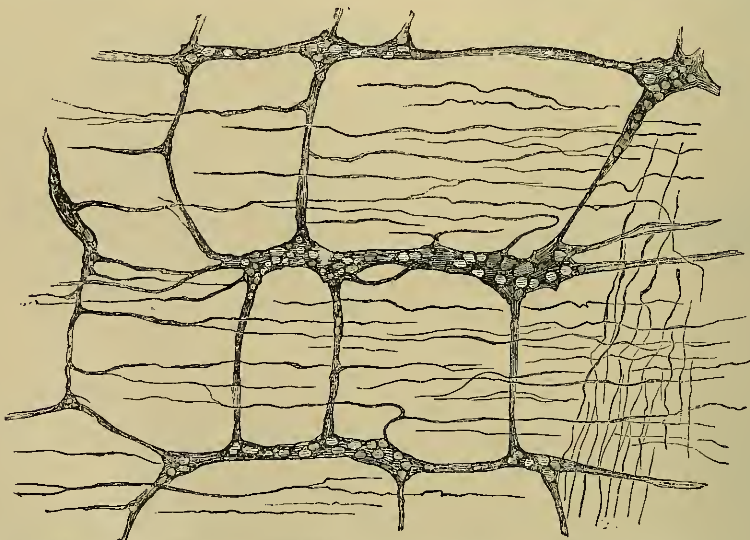


Fig. 128.—Plexus of Auerbach between the two layers of the muscular coat of the intestine. (Cadiat.) Chloride of gold preparation.

mucous membrane form a copious plexus (figs. 124, 126), which receives the central vessels of the villi, and pervades both the mucous and submucous layers—in the latter being of considerable size, and forming, as before mentioned, a close plexus

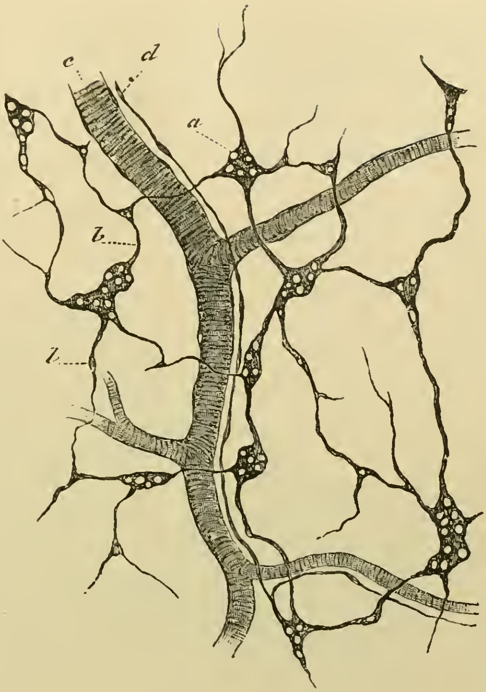


Fig. 129.—Plexus of Meissner, from the submucous layer of the intestine. (Cadiat.) Chloride of gold preparation.

a, *a*, ganglia ; *b*, *b*, cords of plexus ; *c*, a small blood-vessel.

or a sinus around the base of each lymphoid follicle. Another set of lymphatics lies under the peritoneal coat, and is especially developed along a narrow strip at the attachment of the mesentery. In the muscular coat the main plexus is situated between the circular and longitudinal layers of fibres (fig. 127, *l*) ; and there are likewise close plexuses threading the whole thickness of the muscular wall. These lymphatics of the muscular coat are in complete continuity with those of the mucous membrane, and pass into larger vessels at the mesenteric border, which again run into the lacteal vessels of the mesentery.

The **nerves** of the small intestine are chiefly derived from the superior mesenteric plexus. This plexus is formed by nervous branches from the cœliac plexus, the semilunar ganglion, and from the vagus nerve. The plexus and

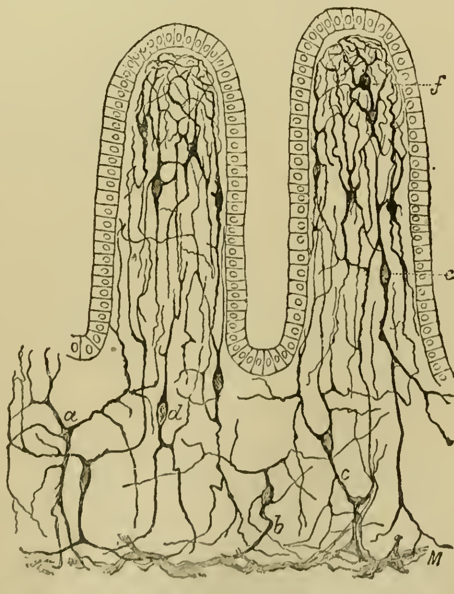


Fig. 130.—Nerve-endings in the small intestine of the guinea-pig. (Cajal.) Silver chromate preparation.

a, *b*, *c*, *d*, small nerve cells belonging to the interglandular plexus of the mucous membrane ; *e*, *f*, corresponding cells belonging to the nerve-plexus of the villi ; *M*, nerve-fibres belonging to the plexus of Meissner, distributed to the muscularis mucosæ.

plexiform branches into which it divides cling at first very closely to the larger divisions of the superior mesenteric artery, and, dividing similarly with the ramifications of the arteries, the branches of the nerves, retaining still a wide plexiform arrangement, pass onwards to the different parts of the intestine between the two folds of the mesentery, and finally, separating somewhat from the blood-vessels, reach the intestine in very numerous branches, to be distributed in its coats. Passing first between the longitudinal and circular layer of the muscular coat, they here form a close gangliated plexus throughout the whole extent of the intestine (fig. 127, *n*, as exhibited under a low power ; also fig. 128). This, which is known as the *plexus*

of Auerbach, or the *plexus myentericus*, and which is principally composed of non-medullated fibres, gives off fine branches to the muscular substance, these first forming a smaller plexus amongst the muscular fibres. Other larger branches pass between the circular bundles of fibres to reach the submucous layer, where they form a second gangliated plexus (*plexus of Meissner*, fig. 129), the threads of which are much finer than those of the intermuscular plexus.

The cords of these plexuses contain two kinds of nerve-fibres, both non-medullated. Those of the one kind pass through the ganglionic enlargements, giving off collateral fibres which ramify around the nerve-cells: they probably take origin in the prevertebral or other more central ganglia. Those of the other kind are finer and more numerous; they are processes of the cells of the ganglionic enlargements and are probably partly passing to their distribution in the muscular layers or in the mucous membrane respectively; partly serving to connect neighbouring ganglia with one another.

From Meissner's plexus nerve-fibres pass to be distributed to the muscular layer of the mucous membrane, breaking up into fine fibrils, which take the direction of the fibre-cells of this layer, whilst other fine fibrils form ramifications in the proper tissue of the mucous coat and villi (fig. 130), and, according to some authors, send branches into the epithelium penetrating between the columnar cells. Upon these ramifications in the mucous membrane and villi, and also upon the ramifications which are distributed to the muscular layers, small cells are found which are thought to be of nervous nature. Similar cell-like enlargements occur on the terminal plexuses within the salivary glands and pancreas (Drasch, Cajal). According to Berkeley the nerves end both between the muscular fibres and within the villi by small pear-shaped or globular dilatations.

SPECIAL CHARACTERS AND RELATIONS OF THE SEVERAL PARTS OF THE SMALL INTESTINE.

Duodenum.—This is the shortest and widest part of the small intestine. In length it measures about 10 to 12 inches (250 to 300 mm.), and in diameter from one-and-a-half to two inches (35 to 50 mm.). In its course it describes a single large curve, which, when the stomach is empty, forms an almost complete ring, its termination in the jejunum being only a little to the left of its commencement (Braune). Distension of the stomach, and the consequent movement of the pylorus towards the right side, makes the curve of the duodenum U-shaped rather than annular. The curve of the duodenum lies in a coronal plane, except at its two extremities which are directed forwards. The concavity embraces the head of the pancreas.

It has no mesentery, and is covered only partially by peritoneum. Its muscular coat is comparatively thick, and its submucous layer towards the pylorus is the seat of the glands of Brunner, already described. The common bile duct and the pancreatic duct open into this part of the intestinal canal.

The duodenum may be divided, for the purpose of anatomical description, into four parts.

The first or **superior** portion is the most variable part, as its length and direction depend upon the position of the pylorus. When the stomach is empty it is fully two inches long, and extends from the pylorus to the right in contact with the quadrate lobe of the liver, and then backwards beneath the neck of the gall-bladder, where it bends sharply downwards to join the second part. If the stomach be fully distended, the commencement of the first part of the duodenum is moved towards the right side, while its termination remains stationary, so that its direction is then almost directly backwards, while its length is diminished to an inch, or even less. Its anterior surface is covered entirely by peritoneum, but its posterior aspect only in the neighbourhood of the pylorus.

Above and in front of it are the liver and gall-bladder. Its close relation to the latter is indicated by the fact that it is often stained by the exudation of bile a few hours after death. Behind it are the portal vein, the gastro-duodenal artery, and the common bile-duct. The neck of the pancreas lies behind and to its inner side.

The second or **descending** portion is about three inches long. It commences just below the neck of the gall-bladder, opposite the right side of the first lumbar

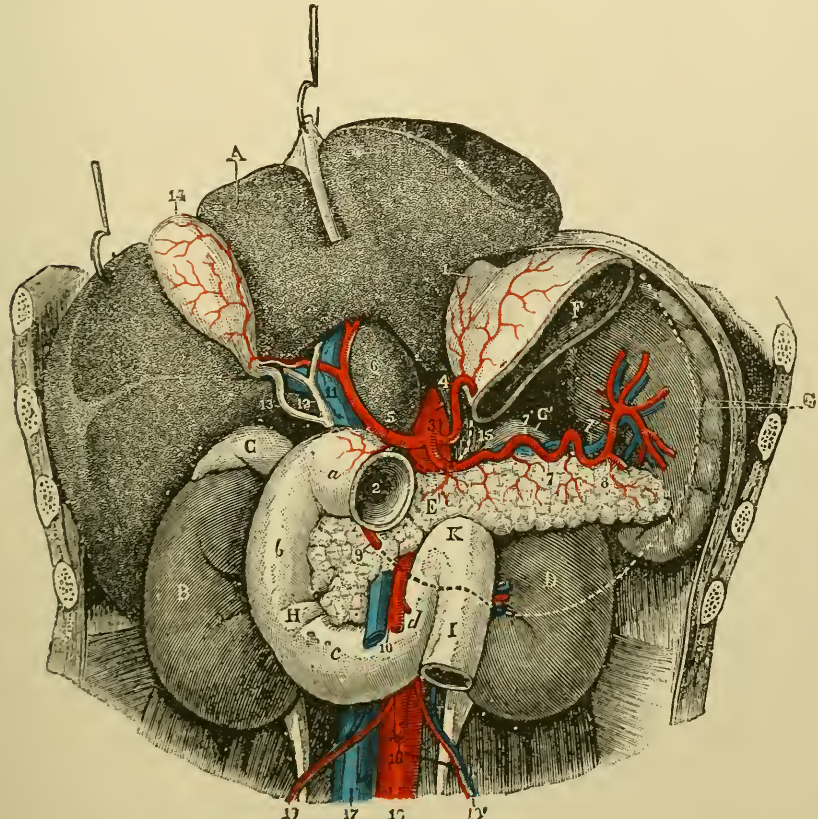


Fig. 131.—View of the liver, duodenum, pancreas, spleen, &c. The greater part of the stomach has been removed, exposing its posterior relations. (Testut.)

A, inferior surface of liver ; B, right kidney ; C, C′, right and left suprarenal capsules ; D, left kidney ; E, pancreas ; F, upper part of stomach ; G, spleen ; H, duodenum with *a*, *b*, *c*, *d*, its four portions ; I, jejunum ; K, duodeno-jejunal junction ; 1, lower end of œsophagus ; 2, pyloric orifice ; 3, cœliac axis ; 4, coronary artery ; 5, hepatic artery ; 6, lobus Spigelii of liver ; 7, 7′, splenic vessels ; 8, left gastro-epiploic artery ; 9, right gastro-epiploic artery ; 10, superior mesenteric vessels ; 11, portal vein ; 12, hepatic duct ; 13, cystic duct ; 14, gall bladder ; 15, left crus of diaphragm ; 16, aorta ; 17, inferior vena cava ; 18, inferior mesenteric vessels ; 19, 19′, spermatic vessels.

vertebra, and passes down to the level of the body of the third or fourth lumbar vertebra, where it turns sharply inwards to join the third part. Its anterior surface usually gives attachment to the transverse meso-colon, and is entirely covered by peritoneum, with the exception of the small interval between the two layers of the meso-colon. This small uncovered area is sometimes considerably increased, owing to the transverse colon being here destitute of a meso-colon, and separated from the duodenum by areolar tissue only. Above the transverse colon the anterior surface is in contact with the liver. The posterior surface has no peritoneal covering, but is connected by areolar tissue to the right kidney and its vessels and the inferior vena

cava. There are considerable variations in the relations of the second part of the duodenum to the right kidney. According to Cunningham, they are probably due rather to variations in the position of the kidney than of the duodenum. As a rule, the duodenum comes in contact with the kidney a little above its hilum, and reaches down to about the level of its lower end. To the left is the head of the pancreas (see fig. 131), which adapts itself to the shape of the intestine on that side, and, according to Verson, some of the longitudinal fibres of the gut are intercalated amongst the contiguous lobes of the gland. The common bile-duct descends behind the left border of this part of the duodenum, and the pancreatic duct accompanies it for a short distance. On opening into this part of the duodenum, the valvulæ conniventes appear numerously, and a downwardly projecting papillary eminence of the mucous membrane is found immediately below one of these, about four inches from the pylorus, on the inner and back part of the intestine, at the apex of which is seen the common orifice of the biliary and pancreatic ducts.

The third or **transverse** portion of the duodenum is between two and three inches long. Beginning on the right of the third or fourth lumbar vertebra, it crosses over to the left side, with a slight upward inclination, and ends to the left of the aorta by curving upwards to join the ascending or terminal part of the duodenum. Its anterior surface is covered by peritoneum at its commencement, but near the median plane it becomes separated from the anterior layer of the mesentery by the superior mesenteric vessels which groove its anterior surface. Behind, it lies against the inferior vena cava and the aorta. On the right side its posterior surface is uncovered by peritoneum, but towards the left the posterior layer of the mesentery is prolonged upwards behind it for a variable distance. Above it is the head of the pancreas.

The fourth or **ascending** portion (Treves) is about two inches long. It passes upwards on the left side of the aorta as high as the upper border of the second lumbar vertebra, where it turns abruptly forwards to join the jejunum, forming the *duodeno-jejunal flexure*. It is covered in front and on the left side by the peritoneum, which often forms on its left side one or two peritoneal pouches called the duodeno-jejunal fossæ, and it lies immediately behind the transverse meso-colon, which separates it from the stomach. It rests on the left psoas muscle, the inner edge of the left kidney is sometimes slightly overlapped by it, and near its upper end the left renal vein passes behind it.

The upper end of this part of the duodenum is maintained in position by a strong fibrous band descending from the left crus of the diaphragm, and the tissue around the cœliac axis. This band, which is better marked in the fœtus and young child than in the adult, contains plain muscular fibres, and is called the *musculus suspensorius duodeni.* In subjects in which the intestines are large and dilated the curve of the duodenum may descend to the level of the iliac crest, but, owing to the support given by the band alluded to, its terminal extremity maintains a nearly uniform position.

As a rule, the second, third and fourth parts of the duodenum together form a U-shaped bend, with the concavity looking upwards, but occasionally the third part passes across the front of the vertebral column, with a considerable degree of obliquity, giving rise to the V-shaped type of duodenal curve. In these cases the distinction between the third and fourth parts is not well marked.

Jejunum and Ileum.—The jejunum, originally so called from its having been supposed to be empty after death, follows the duodenum, and includes the upper two-fifths of the remainder of the small intestine, while the succeeding three-fifths constitute the ileum, so named from its numerous coils and convolutions. Both the jejunum and the ileum are attached to the posterior abdominal wall by an

extensive fold of peritoneum termed *the mesentery.* This mesentery, although greatly frilled out in front to correspond in length with the jejunum and ileum to which it gives support, is attached posteriorly by a comparatively short border (about six inches), which extends from the left side of the second lumbar vertebra obliquely across the third part of the duodenum, aorta, inferior vena cava, and right psoas muscle to the right iliac fossa, where it ends. The length of the mesentery, measured from the parietal attachment to the intestine, varies, being longer about the middle than at either end of the bowel. The average length, according to Treves, may be taken as eight to nine inches. Lockwood found that up to the age of forty years it rarely exceeded eight inches, but after this period of life longer mesenteries occurred with greater frequency. Between the two layers of the peritoneum forming the mesentery are placed, besides some fat, numerous branches of the superior mesenteric artery and vein, together with nerves, lacteal vessels, and lymphatic glands. The convolutions of the jejunum and ileum occupy parts of the middle and lower zones of the abdomen, and a variable number of loops lie in the pelvis. The jejunum lies above and to the left of the ileum, but the coils are so irregular that the position of any individual loop affords but little clue to the part of the intestine to which it belongs. The terminal portion of the ileum is more fixed in position than the other parts of the jejuno-ileum. It generally passes outwards and upwards from the cavity of the true pelvis across the right psoas muscle to join the large intestine, being united to the psoas by the lower part of the mesentery, which here is usually very short.

The character of the intestine gradually changes from its upper to its lower end, so that portions of the jejunum and ileum, remote from each other, present certain well-marked differences of structure. Thus, the ileum is narrower; its coats are thinner and paler; the valvulæ conniventes are small, and gradually disappear towards its lower end; the villi are shorter; and the groups of Peyer's glands are larger and more numerous. The diameter of the jejunum is about one inch and a half, that of the ileum about one inch and a quarter. A given length of the jejunum weighs more than the same of the ileum.

Meckel's diverticulum.—In about one in fifty subjects a pouch or diverticulum is given off from the main tube of the ileum. Its average position above the ileo-colic opening is about 43 inches, but it has been found to vary from 11 to 120 inches. It usually comes off from the ileum on the side opposite to the attachment of the mesentery. As a rule, it is from two to three inches in length, and about the same calibre as the bowel from which it arises. The origin of this diverticulum is probably connected with the persistence of a part of the vitelline duct of early fœtal life. It is not to be confounded with hernial protrusions of the mucous membrane, which may occur at any point.

Variations with age and sex.—Treves found the average length of the small intestine in the new-born child to be 9 feet 5 inches, and he estimates that it grows about 2 feet during the first month of extra-uterine life and a similar amount in the second month, but after this period its rate of growth is very variable. Treves gives the average length of the small intestine in the adult female as 10 inches longer than that of the male; but Rolssen, from measurements on German subjects, found it about 2 feet longer in the male.

THE LARGE INTESTINE.

The large intestine extends from the termination of the ileum to the anus. It is divided into the *cæcum* (with the *vermiform appendix*), the *colon* and the *rectum;* and the colon is again subdivided, according to its direction, into four parts, called the *ascending*, *transverse*, and *descending colon*, and the *sigmoid colon* or *flexure*.

The length of the large intestine is usually about 5 or 6 feet; being about one-fifth of the whole length of the intestinal canal. Its diameter, which for the most part greatly exceeds that of the small intestine, varies at different points and under different conditions, from $2\frac{1}{2}$ inches to less than an inch. It diminishes gradually

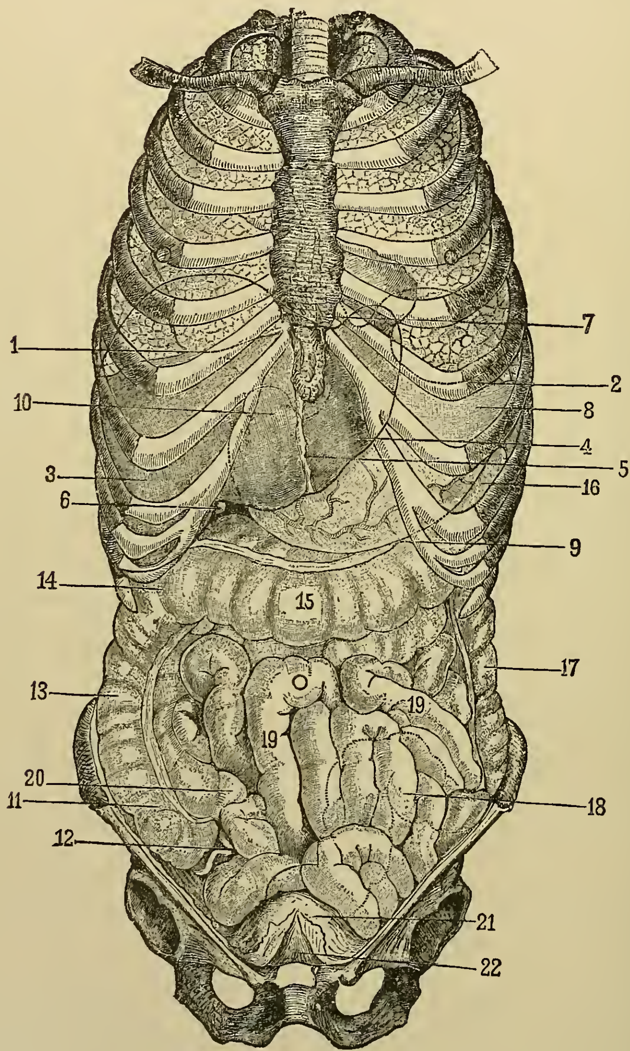


Fig. 132.—Diagram showing the position of the thoracic and abdominal organs. (Rauber after Luschka.)

1, Lower border of the right lung; 2, the same of the left lung; 3, liver, right lobe; 4, liver, left lobe; 5, suspensory ligament of the liver; 6, fundus of gall-bladder; 7, cardia of stomach; 8, fundus of stomach; 9, lower border of stomach; 10, position of pylorus; 11, cæcum; 12, vermiform appendix; 13, ascending colon; 14, right flexure of colon; 15, transverse colon; 16, position of left flexure of colon; 17, descending colon; 18, portion of sigmoid colon, concealed by 19, convolutions of the small intestine; 20, termination of ileum, ascending from left to right; 21, bladder, distended, partly covered by peritoneum; 22, the part of the bladder which is not covered by peritoneum.

from its commencement at the cæcum to its termination at the anus, excepting that there is a well-marked dilatation of the rectum just above its lower end.

In outward form, the greater part of the large intestine differs remarkably from the small intestine ; for, instead of constituting an even cylindrical tube, its surface is thrown into numerous sacculi, marked off from each other by intervening constric-

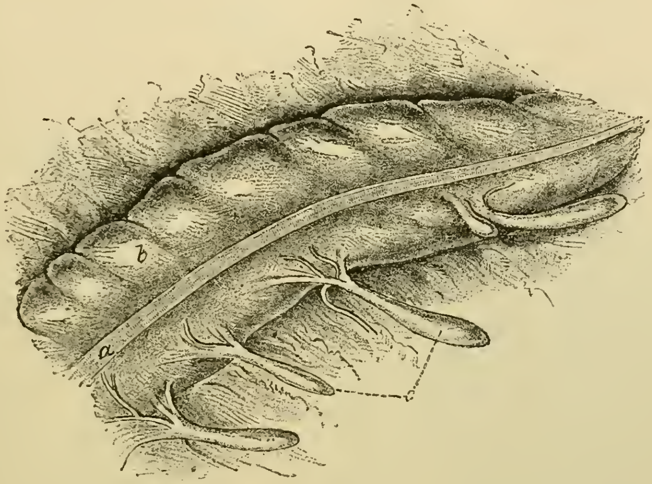


Fig. 133.—Transverse colon, empty and contracted. (Drawn by G. C. R. Harbinson.) *a*, inferior longitudinal band ; *b*, one of the saccules ; *c*, appendices epiploicæ.

tions, and arranged in three longitudinal rows which are separated by three strong flat bands of longitudinal muscular fibres (fig. 133). It can also be distinguished by its appendices epiploicæ (see below), which are not found in connection with the small intestine.

STRUCTURE OF THE LARGE INTESTINE.

The large intestine has four coats, like those of the stomach and small intestine, namely, the serous, muscular, submucous, and mucous.

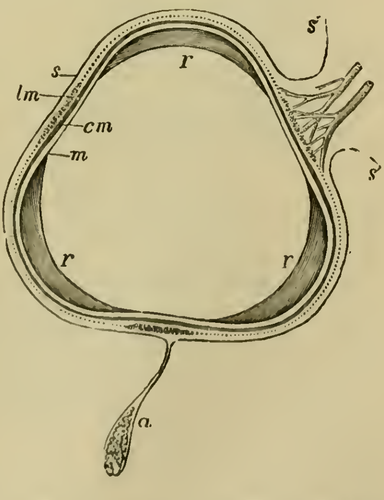


Fig. 134.—Outline sketch of a section of the ascending colon (Allen Thomson). $\frac{3}{4}$

s, serous covering ; *s'*, *s'*, reflection of this at the attached border forming a short wide mesocolon between the folds of which the blood-vessels are seen passing to the colon ; *a*, one of the appendices epiploicæ hanging from the inner border ; *l m*, indicates at the free border one of the three bands formed by the thickening of the longitudinal muscular coat ; the dotted line continued from the margins of these bands represents the remainder of the longitudinal muscular coat; and the thick line within it, marked *c m*, represents the circular muscular layer ; *m*, the mucous membrane at the flattened part ; *r*, the crescentic bands or indentations which divide the sacculi.

The **serous coat** is for the most part similar to that of the small intestine, except that, along the colon and upper part of the rectum, it is prolonged into numerous little projections, which enclose a certain amount of fat, and are termed *appendices epiploicæ*.

The **muscular coat**, like that of the other parts of the intestinal canal, consists of external longitudinal and internal circular fibres.

The *longitudinal* fibres, although found in a certain amount all round the intestine, are, in the cæcum and colon, more thickly collected into three remarkable flat longitudinal bands (fig. 134, *l m* ; fig. 133, *a*). These bands, sometimes called the ligaments of the colon, are about 12 mm. wide, and 1 mm. thick ; they commence upon the cæcum, at the attachment of the vermiform appendix, and may be traced along the whole length of the colon as far as the commencement of the rectum, where they form the two bundles which pass down, one on its anterior and the other on its posterior surface. One of these bands, the *posterior*, is placed along the attached border of the intestine ; another runs along its *anterior* border, and, in the transverse colon, corresponds with the attachment of the great omentum ; whilst the third band (*inner* or *inferior*) is found on the inner border of the ascending and descending colon, and on the under border of the transverse colon. It is near the course of this third band that the appendices epiploicæ are most of them attached (fig. 134, *a*). Measured from end to end, these three bands are shorter than the intervening parts of the tube ; and the latter are thus thrown into the sacculi already mentioned : accordingly, when the bands are removed by dissection, the sacculi are entirely effaced, and the colon, elongating considerably, assumes the cylindrical form. The transverse constrictions seen on the exterior of the intestine, between the sacculi, appear on the inside as sharp ridges separating the cells, and are composed of all the coats. In the vermiform appendix the longitudinal muscular fibres are disposed in a uniform layer.

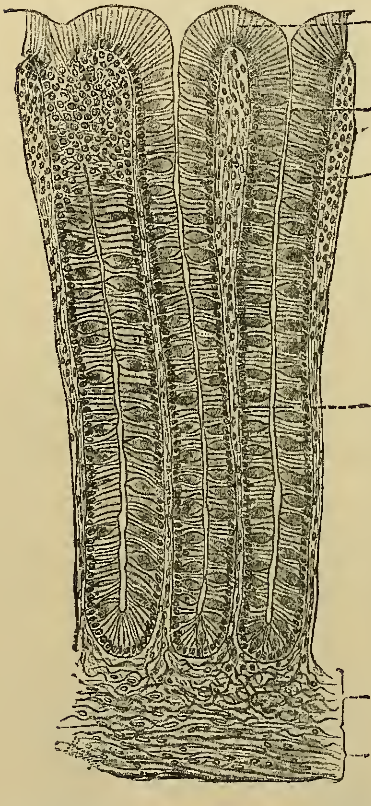


Fig. 135.—Section of the mucous membrane of the colon, man. (Böhm and v. Davidoff.) $\frac{200}{1}$

The *circular* muscular fibres form only a thin layer over the general surface of the cæcum and colon, but are accumulated in large numbers between the sacculi. In the rectum, especially towards its lower part, the circular fibres form a very thick and powerful muscular layer.

The **submucous** or **areolar coat** resembles in all respects that of the small intestine.

The **mucous membrane** differs from that of the small intestine in being smooth and destitute of villi. Viewed with a lens, its surface is seen to be marked all over by the orifices of numerous tubular glands (*crypts of Lieberkühn*) (fig. 135), resembling those of the small intestine, but longer and more numerous, and further distinguished

from them by the large number of mucus-cells which they contain. Indeed in some animals all the cells of these glands may be found to be filled with mucus

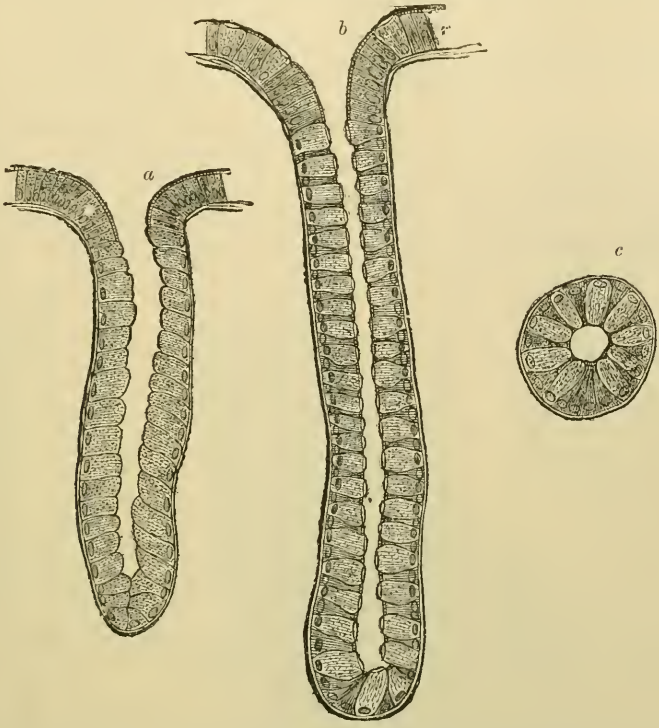


Fig. 136.—Glands of the large intestine. Magnified (from Heidenhain and Klose). *a*, of the rabbit ; *b*, of the dog. *c*, transverse section of a gland of the dog.

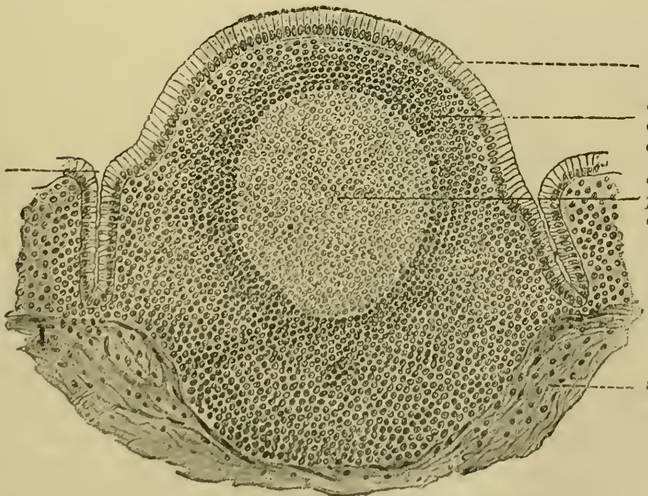


Fig. 137.—Section through a solitary gland of the large intestine of man. (Böhm and v. Davidoff.)

(fig. 136, *a*) ; in others every alternate cell presents this character (fig. 136, *b*, *c*), the cells between being of the ordinary columnar kind. If the glands are stimulated

to active secretion the mucus is discharged and all the cells assume the appearance of ordinary columnar epithelium-cells (Klose).

Scattered over the whole large intestine *lymphoid nodules* are found, similar to the solitary glands of the small intestine. They are most numerous in the cæcum and its vermiform appendix; being placed closely all over the latter.

The epithelium which covers the general surface of the mucous membrane is of

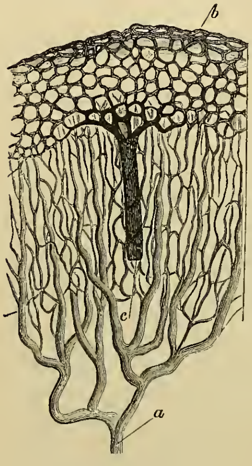


Fig 138.—Blood-vessels of large intestine as seen in vertical section (Kölliker).

a, artery passing up from submucosa; *c*, vein arising from capillary plexus, *b*, which surrounds the mouths of the glands.

the columnar kind, and in every respect similar to that of the small intestine. As in the stomach the mucous membrane consists of areolar connective tissue with a certain amount of retiform tissue, and is bounded next the submucous coat by a layer of plain muscular fibres (*muscularis mucosæ*), which sends prolongations up between the glands to be attached to the basement membrane near the surface, in the same way as in the villi of the small intestine.

Vessels and Nerves.—In the large intestine an arrangement of capillary plexuses and venous radicles obtains, similar to that which has been described in the stomach (fig. 138). The arrangement of the lymphatics is also nearly the same.

Nervous plexuses similar to those of the small intestine are also found in the muscular and submucous coats of the large intestine.

SPECIAL CHARACTERS AND RELATIONS OF THE DIFFERENT PARTS OF THE LARGE INTESTINE.

The Cæcum.—The *intestinum cæcum*, or *caput cæcum coli*, is that part of the large intestine which is situated below the entrance of the ileum (fig. 132, 11). Its length is about 2½ inches, and its breadth about three inches; it is the widest part of the large intestine.

The cæcum is situated in the right iliac fossa, in front of the ilio-psoas muscle and immediately behind the anterior wall of the abdomen above the outer half of Poupart's ligament. It is covered by the peritoneum in front, below and at the sides; behind, the peritoneum is usually reflected from the bowel on to the iliac fascia at the level of the ileo-colic opening, or even still higher up, so that the posterior surface is entirely invested. In about 5 p.c., however, the reflection occurs at a lower level, in which cases the upper part of the posterior surface is uncovered and connected with the iliac fascia by areolar tissue. There is no meso-cæcum.

In the fœtus the cæcum is conical in form, and its apex gives attachment to a slender process called the vermiform appendix. The three longitudinal bands of the large intestine are united at the root of the appendix, but on the cæcum they diverge, one passing up the anterior surface, another on the inner side, and a third on the postero-external aspect. This, the *infantile type* of cæcum, may persist in the adult, Treves found it in two out of one hundred adult subjects. In the great majority of cases, however, the walls of the cæcum begin, even before birth, to grow at unequal rates. The anterior and right walls grow more rapidly than the posterior and left ones, so that the attachment of the vermiform appendix is no longer situated at the

lower end, but is found on the inner and posterior aspect of the cæcum. The three bands, however, are still found to unite at the root of the appendix. The free, rounded and usually blunt lower end of the cæcum thus comes to be formed by the expanded saccule situated between the anterior and postero-external bands. In the third month of fœtal life the cæcum is situated near the median plane just below the liver, and in the process of development it normally passes downwards and to the right, in front of the second part of the duodenum and the kidney towards the right iliac fossa. In the 6th month it lies opposite the lower end of the kidney, and at birth it has usually attained its adult position. This process of descent of the cæcum is liable to be arrested in any part of its course. On the other hand the cæcum is sometimes unusually long and movable, and its free extremity may project down into the true pelvis or even pass across the median plane to the left side. It has been

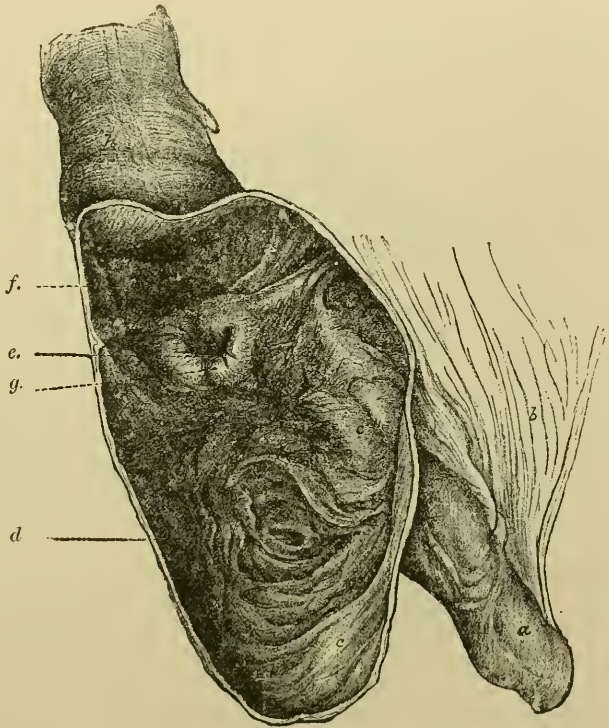


Fig. 139.—Antero-external wall of cæcum and commencement of ascending colon removed to show ileo-colic orifice, &c. From a specimen hardened in situ. (Drawn by G. C. R. Harbinson.)

a, lower end of ileum ; *b*, its mesentery ; *c*, *c*, cæcum ; *d*, orifice of vermiform appendix ; *e*, ileo-colic orifice ; *f*, upper or ileo-colic segment of its valve ; *g*, lower or ileo-cæcal segment ; *h*, ascending colon.

found rotated on its long axis so that the ileum, after passing behind the cæcum, opened on its right side.

Coming off from the inner and back part of the cæcum, a little below the ileo-colic opening is a narrow, round, and tapering portion of the intestine, named the *appendix cæci*, or **vermiform appendix.** The width of this process is usually about 6 mm., and its average length 92 mm. (Berry), but it varies considerably ; thus, Berry found it, in two out of 100 cases, only 31 mm. in length, and Ransshoff has recorded one 230 mm. long. It varies considerably in its position, but will generally be found passing from behind the cæcum either upwards and to the left behind the ileum and mesentery in the direction of the spleen (Treves), or downwards and to the left so as to lie on the brim of the pelvis or even project into that cavity. Sometimes it is situated entirely behind the cæcum, and in this position may be quite free or firmly bound down to the peritoneum. It has a peritoneal fold, the *meso-appendix*, containing its vessels and nerves and attached to above half the length of the appendix, the distal portion being generally quite free and entirely surrounded by peritoneum. The vermiform appendix is usually hollow as far as its extremity ; and its cavity communicates with that of

the cæcum by a small orifice, sometimes guarded by a valvular fold of mucous membrane.

According to the results of Ribbert's observations the cavity of the vermiform appendix exhibits a distinct tendency to undergo obliteration. Thus out of 400 cases examined by him 99 or nearly 25 p.c. had the lumen of the process more or less obliterated. In 50 p.c. of the obliterated cases its distal fourth only, and in 3.5 p.c. the whole process was closed, while the remainder showed intermediate stages. This tendency to obliteration increased with age. Lafforgue did not find such a large proportion of cases showing this tendency, thus out of 200 cases only 7 p.c. belonged to this category. In 3 p.c. the obliteration was total, in 3 p.c. it was closed for a distance of 1 cm. and in 1 p.c. from 2 to 3 cm.

Ribbert has also investigated the length of the appendix at different periods of life. At birth its average length is 34·4 mm., by the 10th year it has increased to 90 mm., during the next 10 years it grows slowly, being at the 20th year 97.5 mm. long. After this period it gradually diminishes in length, thus from 20 to 30 to 95 mm.; from 30 to 40, 87·5 mm.; from 40 to 60, 85 mm.; and the average in subjects over 60 is 82·5 mm. Ribbert found considerable individual variations; in one middle-aged male it was 210 mm., and in a child 5 years old 120 mm. He estimates the length of the appendix as compared with the whole of the large intestine as 1 to 10 in the new-born, and 1 to 20 in the adult.

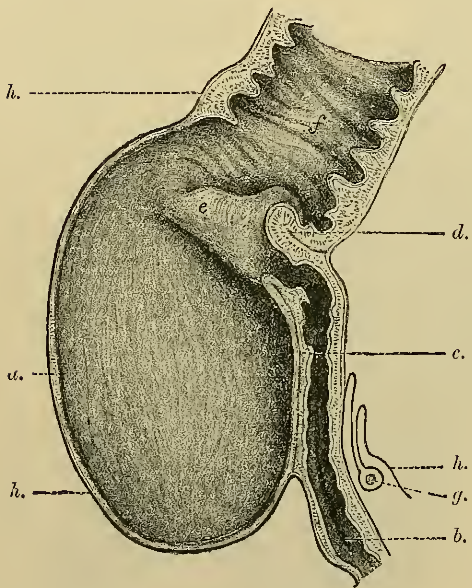


Fig. 140.—Section through the lower end of the ileum, the ileo-colic valve, the cæcum, and ascending colon, to show the relation of the termination of the ileum to the cæcum. The antero-external wall of cæcum removed in fig. 139 is represented as in situ. (J. S.)

a, antero-external wall of cæcum; *b*, cavity of ileum; *c*, lower or ileo-cæcal segment of ileo-colic valve; *d*, upper or ileo-colic segment; *e*, frænum on right side of ileo-colic opening; *f*, ascending colon; *g*, vermiform appendix with its mesentery; *h*, *h*, *h*, peritoneum.

So far as is known, this appendix is peculiar to man and certain of the higher apes, and to the wombat; but in some animals, as in the rabbit and hare, the distal part of the cæcum, being diminished in diameter and thickly studded with lymphoid follicles, may represent a condition of the appendix.

Ileo-colic or **ileo-cæcal orifice and valve.** The lower end of the ileum passes upwards and to the right, being at first internal to and then behind the cæcum, and terminates by opening into the posterior part of the large intestine at the junction of the cæcum and ascending colon (see figs. 139 and 140).

The orifice is generally situated opposite a point on the anterior abdominal wall from 1 to 2 inches internal to and a little above the anterior superior iliac spine. When the colon is opened it appears as a transverse or slightly oblique slit about half an inch in length. This opening is guarded by a valve composed of two segments or folds which project into the large intestine. This is the *ileo-colic* or *ileo-cæcal valve*: it is also called the valve of Bauhin and the valve of Tulpius, although Fallopius had described it before either of those anatomists. The upper of the two segments

(see fig. 140) is horizontal, and the lower and larger oblique. At each end of the aperture these folds coalesce, and are then prolonged as a single ridge on each side for some distance round the cavity of the intestine, forming the *fræna* or *retinacula* of the valve. The opposed surfaces of the valvular folds which look towards the ileum, and are continuous with its mucous surface, are covered like it with villi; while their other surfaces, turned towards the large intestine, are smooth and destitute of villi. In the 5th month of fœtal life both surfaces of the ileo-colic valve possess villi, but by the 9th month the villi on the colic aspect of the valve are represented by only a few stunted processes (Langer).

Each segment of the valve consists of two layers of mucous membrane, continuous with each other along the free margin, and including between them, besides the submucous areolar tissue, a number of muscular fibres, continued from the circular fibres of the ileum and of the large intestine. The longitudinal muscular fibres and the peritoneal coat take no part in the formation of the valve, but are stretched across it uninterruptedly from one intestine to the other; if these be removed and gentle traction be made upon the ileum the valve will gradually become less prominent, and may ultimately disappear by being unfolded and drawn out of the colon. The function of the ileo-colic valve is to prevent the intestinal contents passing from the large into the small intestine. Its valvular action is independent of muscular contraction as air or fluid forced into the large intestine in the cadaver does not generally find its way into the ileum. It is probable that the distension of the cæcum presses the walls of the ileum against one another much in the same way as the urine is prevented from passing from the bladder into the ureters.

Debierre (*Lyon Médical*, Nov., 1885) made a series of experiments to determine the competency of this valve by injecting, per rectum, air or water with the intestines *in situ*, and he found that it permitted these to pass from the large to the small intestine in the proportion of about 2 out of 3. When competent, however, it resisted the pressure of a column of water from 3 to 4 metres in height, the large intestine finally rupturing without a drop of fluid having passed through the ileo-colic orifice. He considered that in the cases of incompetency the cæcal segment of the valve was shorter than the colic, while in the others it was as long or longer.

Birmingham has recorded a case of absence of the ileo-colic valve, and Struthers has described several specimens in which the valve was imperfectly developed.

Various peritoneal folds and fossæ occur in the region of the cæcum, vermiform appendix, end of ileum and commencement of ascending colon, but anatomists are by no means agreed as to their frequency or nomenclature. The following statement is based mainly upon the observations of Lockwood and Rolleston.

Ileo-colic fossa, situated in the angle between the ileum and the commencement of the ascending colon and bounded in front by the ileo-colic fold (*superior ileo-cæcal fold* of Treves).

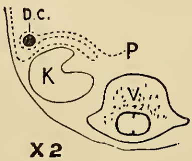
Ileo-cæcal fossa, behind the junction of the ileum and the cæcum. It may extend upwards behind the ascending colon nearly as high as the right kidney and duodenum. The mouth of this fossa is below, and is bounded in front by the ileo-cæcal fold (*bloodless fold* of Treves).

Sub-cæcal fossa, placed directly behind the cæcum. Its fundus may pass upwards behind the ascending colon. It is less frequently met with than the other fossæ.

The vermiform appendix may be concealed within one of these pouches and firmly attached to its walls, constituting what is termed hernia of the appendix. It is very probable that the cases described as examples of absence of the appendix were of this nature with the mouth of the fossa closed.

Colon.—The **ascending colon** is continuous with the cæcum at the level of the ileo-colic opening. It passes upwards through the right lumbar into the hypo-

chondriac region until it comes in contact with the inferior surface of the right lobe of the liver external to the gall-bladder. Here it bends forwards and to the left as the hepatic flexure. The ascending colon is smaller than the cæcum, but larger than the transverse colon. It is overlaid in front by some convolutions of the ileum, and is bound down firmly by the peritoneum which passes over its anterior



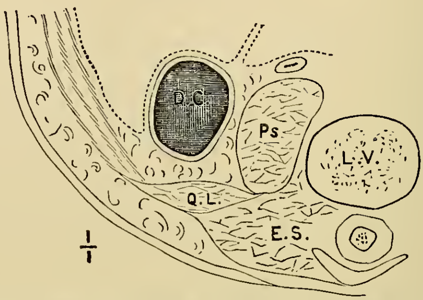


Fig. 141.—Transverse section through the abdomen of a fœtus $3\frac{1}{4}$ inches long. (J. S.)
D.C., descending colon ; P, peritoneum ; K, left kidney ; V, body of vertebra.

Fig. 142.—Transverse section through abdomen of a nine months fœtus. (J. S.)
D.C., descending colon ; Ps, psoas muscle ; Q.L., quadratus lumborum ; E.S., erector spinæ ; L.V., lumbar vertebra.

surface and its sides, and generally leaves an interval in which its posterior surface is connected by areolar tissue with the fascia covering the quadratus lumborum muscle, and with the front of the right kidney. In some cases, however, the peritoneum passes nearly round it and thus forms a distinct though very short meso-colon.

The **transverse colon** extends from the hepatic flexure in the right hypochondrium to the splenic flexure in the left hypochondrium ; between these two points it forms a loop usually directed downwards and forwards. As the transverse colon is considerably longer than the transverse diameter of the abdomen, and possesses a long meso-colon, its position is liable to considerable variations. It generally crosses the abdomen above the level of the umbilicus, but may reach considerably lower.

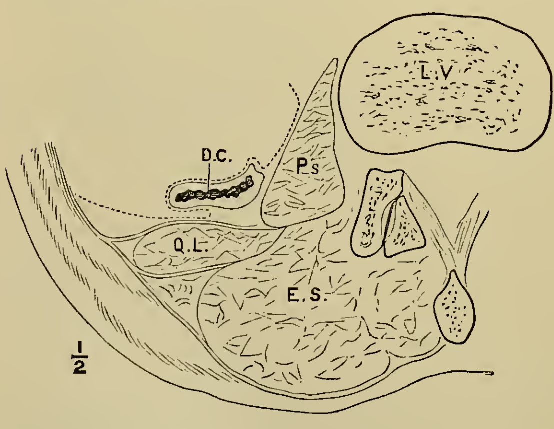


Fig. 143. — Transverse section through the abdomen of a male adult. (J. S.)
References as in Fig. 142.

Above, the transverse colon is in contact with the under surface of the liver, the gall-bladder, the great curvature of the stomach and the lower end of the spleen. It is covered in front by the great omentum. On the right side it crosses in front of the second part of the duodenum to which it may be united by areolar tissue or attached by a short peritoneal fold. In the rest of its course it has behind it some

of the convolutions of the jejunum and ileum to the left of the second part of the duodenum. The two layers of the *transverse meso-colon* are attached to its upper border, and after investing the colon they become continuous with the great omentum. The part of the transverse meso-colon which is often found in front of the duodenum is formed entirely by the great sac, while that to the left of the duodenum is derived from both great and small sacs.

The **descending colon** is continuous with the left extremity of the transverse colon by a sudden bend named the *splenic flexure*, which is higher up and farther back in the left hypochondrium than the hepatic flexure in the right hypochondrium. At this bending there is found a fold of peritoneum, the costo-colic or phreno-colic ligament, which stretches with a lunated free border to the colon from the diaphragm opposite the tenth or eleventh rib. As was pointed out by Haller, it supports the spleen although unconnected with that organ, and may be termed "sustentaculum lienis." From the splenic flexure the colon descends in contact with the outer border of the left kidney. At the lower end of the kidney it usually turns inwards a little and then descends near the outer border of the psoas muscle to the iliac fossa where it joins the sigmoid colon. In a young fœtus (see fig. 141) the descending colon has a relatively long meso-colon which is attached to the abdominal wall internal to the kidney, and passes outwards in front of that organ to join the colon. This meso-colon is obliterated before birth (see fig. 142), probably by a blending of its posterior layer with the peritoneum in front of the kidney. After fœtal life the descending colon is generally covered by peritoneum on its anterior and outer surfaces, the posterior and inner surfaces being uncovered.

Occasionally, especially when the colon is empty, the peritoneum lies behind the outer part of the posterior surface (see fig. 143), but the existence of a distinct *descending meso-colon* is rare.

The **sigmoid colon** may be defined as that part of the colon which is attached to the left iliac fossa from the iliac crest to the brim of the true pelvis. In front of the crest of the ilium it is continuous with the descending colon ; from this point it usually passes downwards, forwards, and somewhat inwards for two or three inches, approaching the anterior abdominal wall internal to the anterior superior iliac spine. This part generally lies in close relation with the fascia in front of the iliacus and is covered by peritoneum on its anterior and lateral aspects only. The rest of the sigmoid colon is generally very movable, being provided with a long meso-colon which is attached transversely in front of the psoas, and becomes continuous internally near the bifurcation of the common iliac artery with the meso-rectum. This portion may be termed the sigmoid loop or the sigmoid flexure proper. It is very variable in its length and position, and frequently forms with the first part of the rectum an omega loop (Treves). In many cases it forms a loop hanging down into the true pelvis ; if the bladder or rectum is distended it is pushed out of the pelvis and may curve upwards as high as the umbilicus, and even in rare cases touch the liver (Treves). Occasionally this loop lies in the iliac fossa in front, and to the outer side of the first part of the sigmoid colon. When its meso-colon is short it simply passes downwards and inwards across the iliac fossa, usually entirely covered in front by the convolutions of the small intestine. The average length of its meso-colon is about 3 inches. On turning upwards the sigmoid loop and its meso-colon the mouth of a peritoneal pouch is sometimes seen, which is called the *inter-sigmoid fossa*. It is somewhat funnel-shaped and extends upwards a variable distance in the direction of the left ureter.

The Rectum.—The lowest part of the large intestine (*intestinum rectum*) extends from the sigmoid loop of the colon to the anal canal. It is situated entirely within the true pelvis to the posterior wall of which it is attached. It is continuous at the pelvic brim near the left sacro-iliac articulation with the sigmoid flexure, and

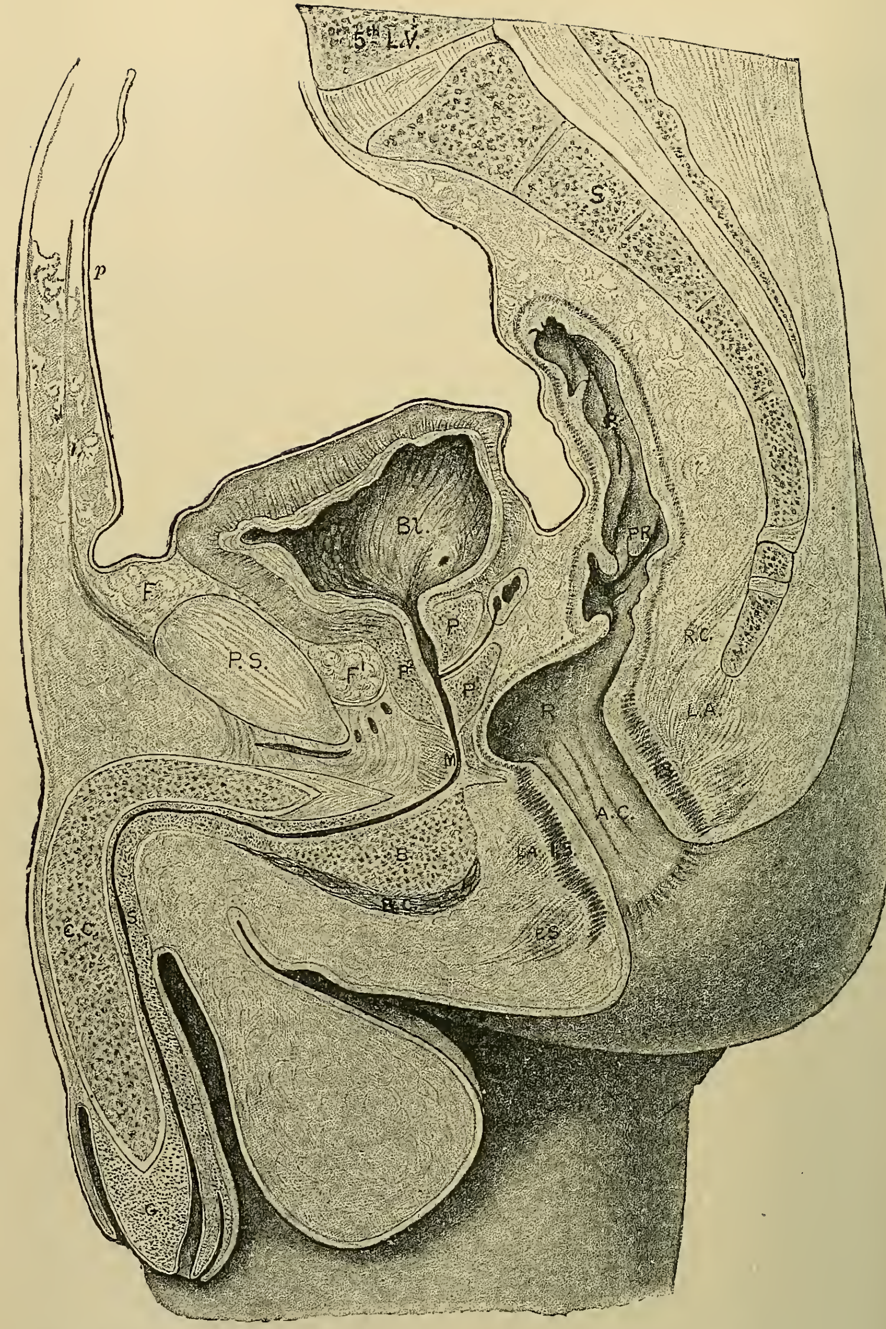


Fig. 144.—Median section of the pelvis and its viscera in an adult male. (J. S.) $\frac{3}{5}$.

The bladder contained about 3 oz. of urine and there were some fæces in the lower part of the rectum. 5th L.V., body of 5th lumbar vertebra ; S, on body of 2nd sacral vertebra ; P.S., pubic symphysis ; R.R., rectum ; P.R., plica dextra recti ; A.C., anal canal with its longitudinal folds of mucous membrane—the columns of Morgagni. The tissues between the anal canal and the coccyx constitute the ano-coccygeal body. I.S., internal sphincter ; E.S., external sphincter ; L.A., levator ani ; R.C., recto-coccygeus muscle ; Bl., bladder ; P, P^1, P^2, prostate gland, P, its middle lobe, between P and P^1, the common ejaculatory duct ; M., membranous part of urethra ; S., spongy part of urethra ; C.C., corpus cavernosum ; G., glans penis ; B., bulb of corpus spongiosum ; B.C., bulbo-cavernosus muscle ; F., supra-pubic pad of fat ; F^1, retro-pubic pad ; *p*, peritoneum.

passing downwards, backwards, and to the right, usually reaches the middle line opposite the third piece of the sacrum. This is generally called the first part of the rectum. At the third sacral vertebra it changes its direction, and curving forwards and downwards as far as the lower end of the prostate gland forms the second part of the rectum which is continuous below with the anal canal.

The first part of the rectum, about 5 or 4 inches long, is covered by peritoneum, and attached by a fold of this membrane called the *meso-rectum* to the front of the sacrum. Some convolutions of the small intestine, or a loop of the sigmoid colon, usually lie against its anterior aspect. In the male a distended bladder will push the intestines upwards and come in contact with it, while occasionally in the female the uterus touches it. On its left side are the ureter and the branches of the internal iliac artery.

The second part of the rectum, 3 or 4 inches in length, is only partially covered by peritoneum. It has no meso-rectum, and its posterior surface is entirely uncovered by the peritoneum. At its commencement it is covered in front and at the sides, but the peritoneum gradually leaves the lateral surfaces, and is finally reflected from the anterior aspect on to the bladder about an inch above the prostate gland. In passing from the rectum to the bladder the peritoneum forms a cul-de-sac, the recto-vesical pouch, which is bounded above on each side by a lunated fold of the serous membrane of which the left is almost always the larger (*posterior false ligaments of the bladder*). Distension of the bladder and rectum tends to draw up the peritoneum and thus diminish the depth of the recto-vesical pouch. The posterior wall of this part of the rectum lies from above downwards on the lower part of the sacrum, the coccyx and the ano-coccygeal body. The anterior wall, which is longer and more curved than the posterior, is in contact with the recto-vesical pouch of peritoneum, a triangular area at the base of the bladder with its lateral boundaries, the vasa deferentia and the vesiculæ seminales, and the prostate gland. Opposite the prostate gland it turns downwards and backwards to end in the anal canal, not unfrequently forming below the prostate a short blind recess (see fig. 144). In the female the second part of the rectum is in relation with the pouch of Douglas and the posterior vaginal wall. Sometimes the sigmoid flexure is displaced towards the right iliac fossa, and the first part of the rectum descends in the pelvis in front of the right half of the sacrum.

Variations according to Age.—The rectum is straighter, more vertical, and relatively larger in the infant than in the adult.

Structure of the rectum.—The rectum differs in some respects from the rest of the large intestine in the arrangement of both its muscular and mucous coats.

The **muscular coat** is thick; the external or longitudinal fibres are found all round the bowel, but are collected chiefly into two bundles, one on the anterior and the other on the posterior aspect. The longitudinal fibres being rather shorter than the other coats give rise to sacculations, which are chiefly situated at the sides of the rectum. The circular fibres are well developed and form thick bundles at the constrictions between the sacculations (Otis). A pair of small bands of plain muscular tissue, which arise from the front of the second and third coccygeal vertebræ, and are also connected with the pelvic fascia, pass with a slight downward inclination to the posterior part of the anal canal (see fig. 144), and become intermingled with its longitudinal fibres. They are known as the recto-coccygeal muscles.

The **mucous membrane** of the rectum is thicker, redder, and more vascular than that of the colon; and it moves more freely upon the muscular coat. When the rectum is empty and contracted it exhibits numerous folds, most of which are obliterated by distension. Several transverse or oblique folds are, however, of a more permanent character, and have been designated "valves of the rectum" (Houston) or "plicæ recti." One of these, usually the largest, is situated on

the right side opposite the reflection of the peritoneum from the rectum to the bladder, and was named by Kohlrausch the "plica transversalis recti." There are generally two other folds, both on the left side, one about an inch above, and the other about the same distance below, the fold on the right side. From the position and projection of these folds they may more or less impede the introduction of instruments. The dilatation of the rectum between the anal canal and the lowest of these folds is called the *rectal ampulla.* (For the appearance of these folds on rectal inspection with the body in the genu-pectoral position, see Otis, "The Sacculi of the Rectum," Leipzig, 1887.)

The anal canal and its muscles.—The terminal portion of the alimentary canal, which is surrounded by the sphincters of the anus, may be termed the anal canal. It is an antero-posterior slit in the pelvic floor ; its lateral walls being in opposition, it differs in this respect from the lower part of the rectum, which when empty appears as a transverse slit (fig. 145). The anal canal is directed downwards

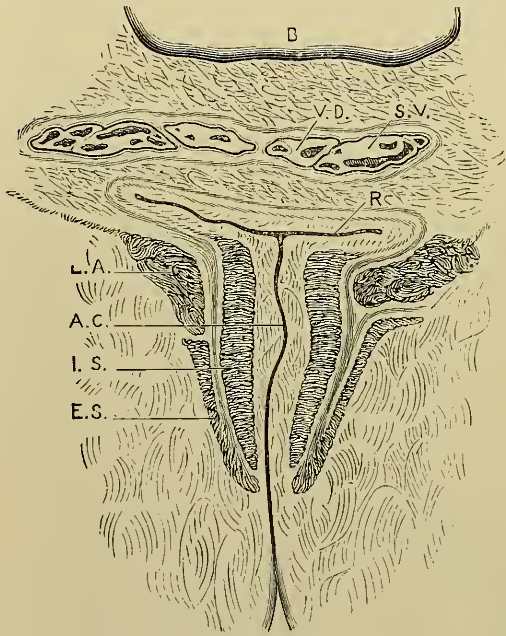


Fig. 145.—A TRANSVERSE AND NEARLY VERTICAL SECTION OF ADULT MALE PELVIS ; THE SECTION PASSED FROM ABOVE DOWNWARDS AND SLIGHTLY BACKWARDS. Life size. (J. S.)

B., cavity of bladder ; V.D., vas deferens ; S.V., seminal vesicle ; R, second part of rectum ; A.C., anal canal ; L.A., levator ani ; I.S., internal sphincter of anus ; E.S., external sphincter of anus.

and backwards, and measures fully an inch in length when the rectum is empty, but is shorter when the rectum is distended. Its antero-posterior extent is from half to three-quarters of an inch (see fig. 144). It is bounded behind by the ano-coccygeal body, and at the sides by the fat of the ischio-rectal fossæ. Its anterior relations differ in the two sexes ; in the male the bulb of the corpus spongiosum lies a little in front of it, while in the female it is separated from the vulval opening, and the lower end of the vagina by the perineal body.

In the skin around the anus and about a centimeter from its margin is a circular zone of large sweat glands which are known as the *circumanal glands.* At the anus the epidermis is continued for a short distance into the aperture, but becomes gradually thinner and finally is replaced by the columnar cells of the mucous membrane. The crypts of Lieberkühn do not appear immediately; there is a narrow zone of mucous membrane destitute of glands.

The mucous membrane of the anal canal is thrown into 4 or 5 longitudinal folds on each side which were named by Morgagni the *columns of the rectum.* These folds contain longitudinal muscular fibres (apparently part of the muscularis mucosæ) which terminate both superiorly and inferiorly in elastic tissue (Treitz).

The muscles which close the anal canal are the internal and external sphincters

and the levatores ani. The external sphincter and the levator ani will be found described in Vol. II. pt. 2.

The **internal sphincter** is a pale muscle, composed of non-striped fibres, which surrounds the entire length of the anal canal. It is of nearly uniform thickness, about 4 mm., in its entire extent, and ends almost abruptly above, where it becomes continuous with the much thinner circular fibres of the rectum.

Vessels and Nerves of the Rectum and Anal Canal.—The **arteries** of the rectum spring from three sources, viz., the *superior hæmorrhoidal* from the inferior mesenteric, the *middle hæmorrhoidal* from the internal iliac, and the *inferior hæmorrhoidal* from the pudic artery. Of these the most important is the superior hæmorrhoidal. It is a single vessel which descends in the meso-rectum, and then divides into two branches which form loops, one on each side of the rectum, with the convexity of the loop directed downwards. From these loops several branches arise which pass downwards, pierce the muscular coat, and run in a longitudinal direction under the mucous membrane, and anastomose freely with one another. In the anal canal they lie in the longitudinal folds of the mucous membrane and reach as far as the verge of the anus. The arrangement of the **veins** is somewhat similar ; they commence in little dilatations at the lower end of the anus, ascend beneath the mucous membrane for about three inches, where they communicate with one another to form the hæmorrhoidal plexus, and then pierce the muscular coat by 5 or 6 openings, and pass upwards to the superior hæmorrhoidal vein, which forms the beginning of the inferior mesenteric trunk. According to Quénu, the hæmorrhoidal plexus communicates freely with the tributaries of the inferior hæmorrhoidal, but only slightly with those of the middle hæmorrhoidal.

The **lymphatics** enter some glands placed in the hollow of the sacrum (see Vol. II., Pt. 2, p. 551).

The **nerves** are very numerous, and are derived from both the cerebro-spinal and the sympathetic systems. The former consist of branches derived from the sacral nerves, and the latter of offsets from the inferior mesenteric and hypogastric plexuses. Experiments upon animals have shown that the longitudinal muscular fibres of the rectum are supplied with motor fibres from the anterior roots of certain of the sacral nerves (2nd and 3rd, and in part the 1st in the dog), which nerves also supply inhibitory fibres to the circular coat, whereas the fibres of the hypogastric plexus which supply the circular muscular tissue with motor fibres, are derived from white rami communicantes of the anterior roots of certain of the lumbar nerves, which join the sympathetic chain and lose their medullary sheath before passing to their distribution in the muscular coat. Pilliet has noted the presence of Pacinian corpuscles upon some of the nerves distributed to the anal mucous membrane.

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THE LIVER.

The liver is the largest gland in the body, and by far the most bulky of the abdominal viscera. Its shape is liable to considerable variations, but is essentially that of a right-angled triangular prism, with the right angles rounded off. If the upper part of the abdomen be supposed to be occupied by a cuboidal mass divided into two by a cut passing from its upper left edge to its lower right one, the position and shape of the liver will be represented by the upper and right half of this mass. The liver has five surfaces, viz., anterior, posterior, superior, inferior, and right. The anterior and posterior surfaces are triangular, one of their angles, which is situated above and on the right side, being rounded off, while the remaining two are acute, and placed one above and on the left side, the other below and on the right.

Dimensions and Weight.—The greatest vertical extent of the liver is near its right surface, where it measures, on an average, from five to seven inches. This diameter gradually diminishes from right to left, the organ ending on the left side in a thin sharp border. Its greatest transverse diameter is usually one or two inches more than the corresponding vertical one, but is sometimes less. The antero-posterior diameter is greatest on the right side of the vertebral column, and just above the right kidney; here it measures from four to six inches. In front of the vertebral column its antero-posterior extent is considerably reduced, being in the median plane only about two-and-a-half to four inches. The ordinary bulk of the liver is 90 to 100 cubic inches, and its average weight between 50 and 60 ounces. According to the facts recorded by Reid, the liver weighed, in 43 cases out of 82, between 48 and 58 ounces in the adult male; and, in 17 cases out of 36, between 40 and 50 ounces in the adult female. It is generally estimated to be equal to about 1-36th of the weight of the whole body; but in the fœtus, and in early life, its proportionate weight is greater. Thus at birth it is about 1-18th of the body weight.

Vierordt (Anatom. Daten u. Tabellen) gives the following approximate numbers for the adult:—Weight, male 1,579 g., female 1,526 g.; volume, 1,720 cubic cent.; length, 320 mm.; sagittal diameter, 200 mm.

The specific gravity of the liver is between 1·05 and 1·06; in fatty degeneration this is reduced to 1·03, or even less.

The liver is solid to the touch, but easily torn. Its colour is a dull reddish-brown, with frequently a dark purplish tinge along the anterior margin. During life it is probably softer than after death, as when hardened *in situ* it shows impressions for all the viscera that are in contact with it.

The liver is divided into two unequal lobes, a *right* and a *left*, and on the under and posterior surfaces of the right lobe are three secondary lobes, named the *lobe of Spigelius*, the *caudate* or *tailed lobe*, and the *quadrate lobe*.

The right and left lobes are separated from each other on the under surface by the *umbilical fissure* (fig. 147, *u.f.*), and on the posterior surface by its prolongation, the *fissure for the ductus venosus* (*f.d.v.*). On the anterior and upper surfaces the only indication of a separation between them is the line of attachment of the fold of peritoneum, termed the *falciform* or *broad ligament*, except below, where the umbilical fissure is prolonged upwards on the anterior surface for a short distance, forming the *umbilical notch* (fig. 146). The right lobe is much larger and thicker than the left, which is very variable in extent, and ordinarily constitutes only about one-fifth or one-sixth of the entire gland.

Surfaces.—The **anterior** (fig. 146) is frequently the largest of all the surfaces. It is smooth and triangular, and united with the upper and right surfaces by

rounded borders, but separated from the under surface by a sharp margin, which can often be felt in the living body. This surface is formed by both the right and left lobes, the separation between which is indicated by the umbilical notch and the attachment of the falciform ligament. To the right of the umbilical notch the lower margin of this surface presents an excavation situated over the fundus of the gall-bladder. The peritoneum covers the whole of the anterior surface, except along a narrow line between the two layers of the above-named ligament.

The **posterior surface** (fig. 147) is triangular, very uneven, only partially covered by peritoneum, and not so distinctly marked off from the under surface as is the anterior. It includes :—1. A portion of the left lobe which lies immediately in front of the cardia, and abuts against the anterior wall of the omental sac. The upper part (fig. 147, *C*), which is in contact with the cardia, is concave, but the remainder

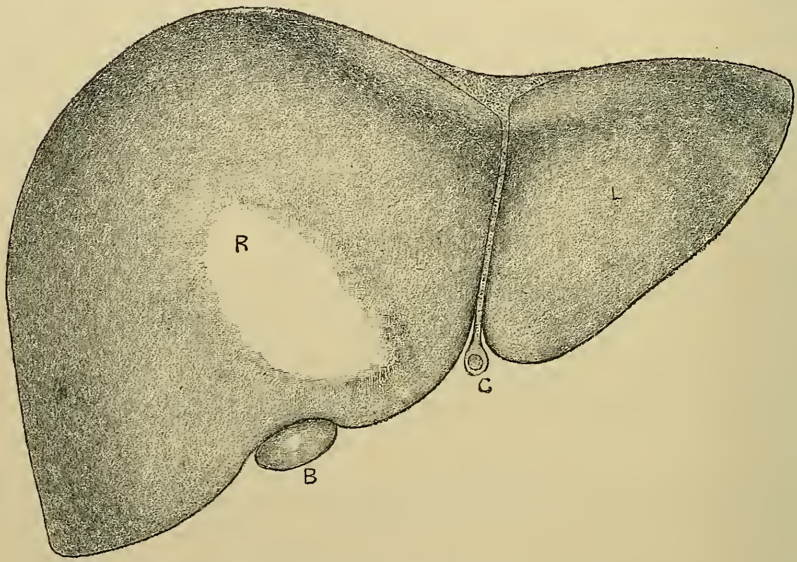


Fig. 146.—Anterior surface of the liver. (J. S.)
R, right lobe ; L, left lobe ; B, fundus of gall-bladder ; C, round ligament of liver.

forms a considerable protuberance (*omental tuberosity*, *t.o.*) projecting over the lesser curvature of the stomach. This posterior surface of the left lobe passes with a gradual slope into the under surface. 2. The *Spigelian lobe* (*lobulus Spigelii*, *L.S.*) and the *caudate lobe* (*L.C.*). The latter is a narrow ridge prolonging the Spigelian lobe towards the under surface of the right lobe. It runs behind the portal fissure, and lies immediately above the foramen of Winslow. The Spigelian lobe is separated from the left lobe by the fissure of the ductus venosus, and from the posterior surface of the right lobe by the fossa for the vena cava. Its free surface looks directly backwards, and is nearly vertical and slightly concave from side to side. Superiorly it slopes over towards the upper surface of the organ, while its inferior border is divided by a notch into a right part, which joins the caudate lobe, and a left portion, ending in a small tubercle (*tuber papillare,* His). The Spigelian lobe is opposite the tenth and eleventh dorsal vertebræ. It rests against the diaphragm, the two opposing surfaces being covered by peritoneum belonging to the lesser sac. Behind its upper left hand corner the lower end of the œsophagus passes obliquely into the cardia. Lower down behind the left border is the end of the thoracic aorta, separated, however, from the liver by the diaphragm. 3. A strip

of the right lobe $2\frac{1}{2}$ to 3 inches broad; convex for the most part, except for a small depression at its lower and mesial corner, which receives the right supra-renal capsule (*impressio supra-renalis, i.sr.*). In consequence of the separation of the layers of the coronary ligament, this surface of the right lobe (fig. 147, *X*) is not covered by peritoneum except at its right extremity. It rests against the ascending part of the diaphragm, and superiorly passes gradually into the upper surface. Inferiorly it is separated by a sharp margin from the renal impression on the under surface. This margin is sloped obliquely downwards and outwards, following the line of the eleventh and twelfth ribs. The mesial border often projects over the inferior vena cava.

The **upper surface** of the organ is smooth, covered by peritoneum and

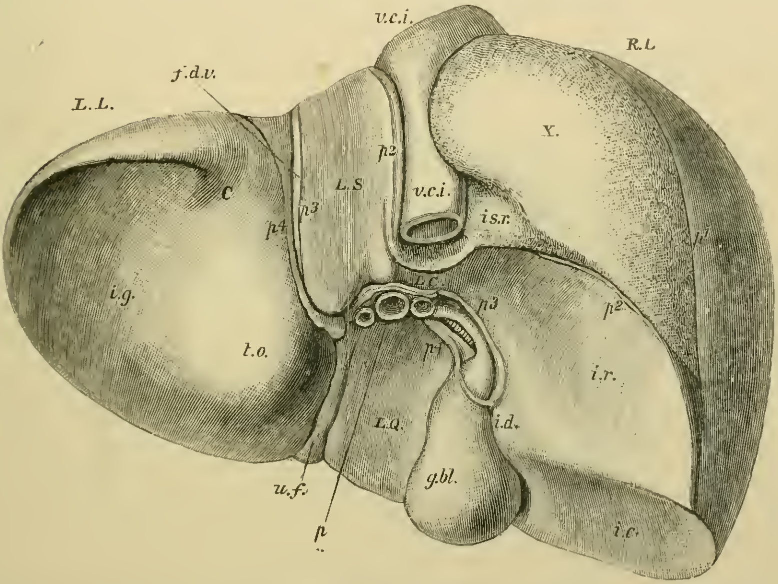


Fig. 147.—The liver of a young subject, sketched from below and behind. (The drawing has been made by Mr. Wesley from a cast prepared under the direction of Prof. His of Leipzig.) $\frac{1}{2}$

R.L., right lobe; *L.L.*, left lobe; *L.S.*, lobe of Spigelius; *L.C.*, caudate lobe; *L.Q.*, quadrate lobe; *p*, portal fissure; *u.f.*, umbilical fissure; *f.d.v.*, fissure of the ductus venosus; *g.bl.*, gall-bladder; *v.c.i.*, vena cava inferior; *i.g.*, impression on the under surface of the left lobe corresponding to the stomach; *C*, position of the cardia; *t.o.*, projection of the posterior surface of the left lobe against the lesser omentum (tuber omentale, His); *i.c.*, impressio colica; *i.r.*, impressio renalis; *i.sr.*, impressio supra-renalis; *i.d.*, impressio duodenalis; p^1, p^2, p^3, p^4, lines of reflection of the peritoneum; *X*, surface of the liver uncovered by peritoneum.

exactly moulded to the under surface of the diaphragm. Near the median plane it gives attachment to the falciform ligament. It has two rounded convex portions separated by a shallow concavity corresponding to the situation of the heart. The right convexity is much larger and more prominent than the left one.

The **under surface** is concave, uneven, and looks downwards, backwards, and to the left. It is invested with peritoneum everywhere except where the gall-bladder (fig. 147, *g.bl.*) is adherent to it, and at the portal fissure (*p*), where the fold of peritoneum termed the lesser omentum, which encloses the blood-vessels and ducts of the viscus, comes off, and passes to the smaller curvature of the stomach. The under surface of the left lobe (*i.g.*) is moulded over the subjacent cardiac part of the stomach, and over that part of the anterior surface of the stomach which is next to the lesser curvature.

The under surface of the right lobe may be regarded as divided by the fossa which lodges the gall-bladder (*fossa seu impressio vesicalis*) into two unequal portions. Of these the lateral is by far the larger, and is mainly occupied by two large shallow concave impressions, one situated anteriorly being produced by the hepatic flexure of the colon (*impressio colica, i.c.*), the other and posterior one being caused by the right kidney (*impressio renalis, i.r.*). These two impressions are separated from one another by a low ridge. At the mesial border of the renal impression is a third narrow and but slightly marked impression, corresponding to the descending part of the duodenum (*impressio duodenalis, i.d.*).

The mesial of the two parts into which the fossa of the gall-bladder subdivides the under surface of the right lobe is somewhat rectangular and oblong, having the antero-posterior diameter greater than the transverse; it is known as the *quadrate lobe* (*L.Q.*). It is immediately over the pyloric end of the stomach and the

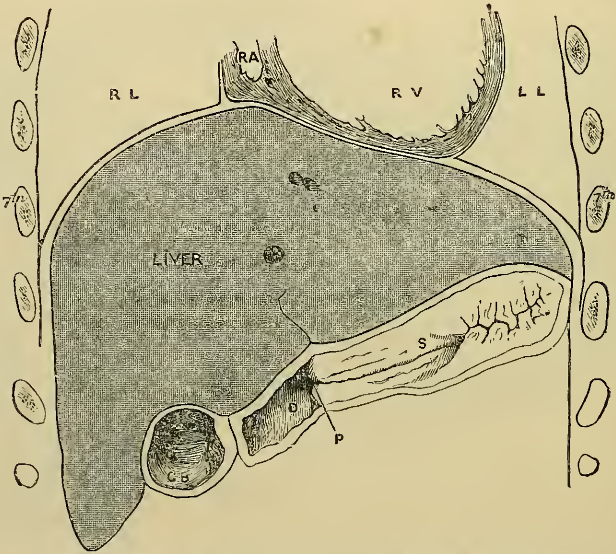


Fig. 148.—Coronal section of part of thorax and abdomen of female child, aged one year and ten months. The liver in the infant is relatively larger than in the adult. (J. S.)

R.L., right lung; L.L., left lung; R.A., right auricle of heart; R.V., right ventricle, distended with injection; S, stomach, empty and contracted; P, pylorus, situated in the median plane just beneath the longitudinal fissure of liver; D, first part of duodenum in contact with quadrate lobe of liver; G.B., gall-bladder, which was full of bile.

commencement of the duodenum, and when these are distended they impress upon the surface of the quadrate lobe a slight concavity. It is bounded on the left by the umbilical fissure, and behind by the transverse or portal fissure.

The **right surface** is convex from before backwards, and often slightly convex from above downwards. It unites with the upper, anterior, and posterior surfaces by rounded borders, but is separated below from the under surface by a sharp edge.

Fissures.—The *transverse* or *portal fissure* (fig. 147, *p*) is the most important, because it is here that the great vessels and nerves enter, and the hepatic duct passes out. It lies transversely between the quadrate lobe in front and the caudate and Spigelian lobes behind, and meets the longitudinal fissure nearly at right angles.

The *longitudinal fissure*, between the right and the left lobes, is divided into two parts by its junction with the transverse fissure. The anterior part (*u. f.*), named

the *umbilical fissure*, contains the umbilical vein in the fœtus, and the remnant of that vein in the adult, which then constitutes the round ligament. It lies between the quadrate and left lobes of the liver, the substance of which often forms a bridge (*pons hepatis*) across the fissure, so as to convert it partially or completely into a canal. The posterior part (*f.d. v.*) is named the *fissure of the ductus venosus* ; it is situated between the lobe of Spigelius and the left lobe, and lodges the ductus venosus in the fœtus, and in the adult a slender cord or ligament into which that vein is converted.

The *fissure* or *fossa of the vena cava* (*v. c. i.*) is situated at the back of the liver between the Spigelian lobe and the right lobe, and is separated from the transverse fissure by the caudate lobe. It is at the upper part of this fossa that the blood leaves the liver by the hepatic veins, which end here in the vena cava. As in the case of the umbilical fissure, the substance of the liver in some cases unites around the vena cava, and encloses that vessel in a canal.

The transverse and umbilical fissures are on the under surface of the liver ; the fissure of the ductus venosus and that for the vena cava are on the posterior surface.

Ligaments and Omentum.—The ligaments of the liver are, with one exception, only reflections of serous membrane. Thus the name *coronary ligament* is given to the reflection of peritoneum around the somewhat triangular portion of the posterior surface of the liver (fig. 147, X), which is here immediately adherent to the diaphragm. These reflections are continued at either end into a fold—the *right and left lateral ligaments*, of which the left is the longer and more distinct, the right being sometimes scarcely perceptible. Another of these so-called ligaments is the *falciform*, *broad*, or *suspensory ligament*, a wide thin membrane, formed of two cohering layers of peritoneum continuous behind with the upper layer of the coronary and left lateral ligament respectively. By one of its margins it is connected with the under surface of the diaphragm, and with the sheath of the right rectus muscle of the abdomen as low as the umbilicus ; by another it is attached along the upper and anterior surfaces of the liver ; the remaining margin is free, and contains between its layers the *round ligament*, a dense fibrous cord, the remnant of the umbilical vein of the fœtus, which ascends from the umbilicus within the lower edge of the falciform ligament, and enters the longitudinal fissure on the under surface.

In addition to the folds called ligaments, the liver gives attachment to two layers of peritoneum, which pass between the liver and stomach, and form the *gastro-hepatic* or *lesser omentum*. This is attached to the transverse fissure of the liver, and the posterior part of the longitudinal fissure, or the fissure of the ductus venosus, and near its right free border encloses between its two layers the bile-duct, portal vein, hepatic artery, lymphatics, and nerves.

Position with regard to the abdominal and thoracic parietes.—The liver occupies the right hypochondriac and epigastric regions, extending also frequently into the left hypochondriac and right lumbar. In almost the whole of its extent it is separated from the surface of the body by the lower ribs and costal cartilages, but in the subcostal angle a small part of the anterior surface lies directly behind the abdominal wall. Above it is accurately adapted to the vault of the diaphragm, and the right lobe reaches higher beneath the ribs than the left, corresponding thus with the more elevated position of the diaphragm on the right side. The liver is separated by the diaphragm from the concave base of the right lung, the thin margin of which descends a short distance between the thoracic wall and the solid mass of the liver.

The right surface is protected by the seventh to the 11th ribs, and the anterior surface by the fifth, sixth, seventh, eighth, and ninth costal cartilages, with the

anterior parts of the corresponding ribs, and by the ensiform cartilage, the diaphragm, of course, being interposed. The upper limit of the liver may be indicated on the anterior wall of the chest by a line which crosses the median plane at the lower end of the body of the sternum. On the right side this line must be extended outwards and slightly upwards, so that in the mammary line it is near the upper edge of the fifth rib, from which point it descends towards the seventh rib in the mid-axillary line. On the left side the line passes nearly horizontally outwards, being slightly overlapped by the heart.

Its lower limit on the right side practically coincides with the lower edge of the thoracic wall as far inwards as the tip of the ninth costal cartilage. About this point the line representing its lower edge passes upwards and to the left, to near the tip of the eighth costal cartilage. It is then continued in the same direction across the left costal cartilages, to meet the left end of the upper limit at an acute angle.

The situation of the liver is modified by the position of the body, and also by the movements of respiration. Thus, in the upright or sitting position it descends to just below the lateral margin of the thorax, but in the recumbent posture ascends half an inch or an inch higher up, and is entirely covered by the ribs, except a small portion opposite the sub-costal angle. During a deep inspiration the liver also descends below the ribs, even in the recumbent posture, and in expiration retires up behind them. In females it is often permanently forced downwards below the costal cartilages, owing to the use of tight stays; sometimes it reaches nearly as low as the crest of the ilium, and in many such cases its convex surface is indented from the pressure of the ribs.

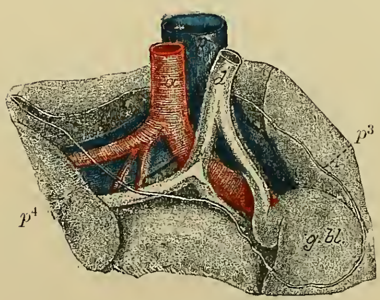


Fig. 149.—Sketch of a portion of the under surface of the liver, showing the arrangement of the vessels in the portal fissure. (G. D. T.)

a, hepatic artery; *p*, portal vein; *d*, bile-duct; *g.bl*, gall-bladder; p^3, p^4, lines of reflection of the peritoneum.

The position of the liver is also affected by the condition of its neighbouring organs. Thus, when the intestines are distended and the abdomen prominent, the liver is pushed upwards, and its vertical extent diminished, while when these are empty and the abdominal wall retracted, the liver is compressed from before backwards, and the inferior surface is nearly in the same plane as the posterior. Again, with the distension of the stomach the left lobe of the liver is pushed over towards the right side.

Vessels and Nerves.—The two vessels by which the liver is supplied with blood are the *hepatic artery* and the *portal vein.* The hepatic artery (fig. 149), a branch of the cœliac axis, is small in comparison with the organ to which it is distributed. It enters the transverse fissure, and there divides into a right and left branch for the two principal lobes.

By far the greater part of the blood which passes through the liver—and in this respect it differs from all other organs of the human body—is conveyed to it by a large vein, the portal vein, or vena portæ (fig. 149). This vein is formed by the union of the veins of the stomach, intestines, pancreas, and spleen. It enters the transverse fissure, or porta hepatis, and, like the hepatic artery, there divides into two principal branches.

The hepatic artery and portal vein, lying in company with the bile-duct, ascend

to the liver between the layers of the gastro-hepatic omentum, in front of the foramen of Winslow, and thus reach the transverse fissure. In this course the bile-duct is to the right, the hepatic artery to the left, and the large portal vein behind the other two. They are accompanied by numerous lymphatic vessels and nerves. The branches of the three vessels accompany one another in their course through the liver nearly to their termination, and are surrounded for some distance by an areolar investment, the so-called capsule of Glisson, which is prolonged into the interior of the organ.

The **hepatic veins**, which convey the blood away from the liver, pursue through its substance an entirely different course from the other vessels, and pass out at its posterior surface, where, at the upper part of the fossa already described, they end by two or three principal branches, besides a number of smaller ones, in the vena cava inferior.

The **lymphatics** of the liver, large and numerous, form a deep and a superficial set. Their mode of origin and their course will be afterwards described.

The **nerves** are derived partly from the cœliac plexus, and partly from the pneumogastric nerves, especially from the left pneumogastric. They enter the liver supported by the hepatic artery and its branches, along with which they may be traced in the portal canals.

EXCRETORY APPARATUS.—The excretory apparatus of the liver consists of the *hepatic duct*, the *cystic duct*, the *gall-bladder*, and the *common bile-duct.*

The **hepatic duct**, formed by the union of a right and left branch, which issue from the bottom of the transverse fissure and unite at a very obtuse angle, descends to the right, within the gastro-hepatic omentum, in front of the vena portæ, and with the hepatic artery to its left. Its diameter is about $\frac{1}{6}$th of an inch (4 mm.), and its length nearly two inches (one inch only, according to Luschka). At its lower end it meets with the cystic duct, descending from the gall-bladder, and the two ducts uniting together at an acute angle form the common bile-duct.

The **gall-bladder** (fig. 147, *g.bl.*), is a pear-shaped membranous sac, 3 or 4 inches (75 to 100 mm.) long, about an inch and a half (35 mm.) across its widest part, and capable of containing from 8 to 12 fluid-drachms (30 to 50 cub. cent.). It is lodged obliquely in the fossa before mentioned on the under surface of the right lobe, with its large end or *fundus*, which projects beyond the anterior border of the liver, directed forwards, downwards, and to the right, whilst its *neck* is inclined in the opposite direction. Its upper surface is attached to the liver by areolar tissue. Its under surface and fundus are covered by the peritoneum, which is reflected over them from the surface of the liver. In rare cases the peritoneum completely surrounds the gall-bladder, which is then suspended by a sort of mesentery from the under surface of the liver. The fundus generally touches the abdominal parietes immediately beneath the margin of the thorax, opposite the ninth costal cartilage. It is, however, subject to considerable variations. Thus, if the liver be small, or the gall-bladder empty, it often fails to reach the abdominal wall. In cases of distension of the stomach it may be displaced to the right. The gall-bladder rests below on the commencement of the transverse colon ; and, farther back, it is in contact with the duodenum, and sometimes with the pyloric extremity of the stomach. The neck, gradually narrowing, is curved like the letter S, and then, becoming much constricted, and changing its general direction altogether, it bends downwards and terminates in the cystic duct.

The gall-bladder is supplied with blood by the cystic artery, a branch of the right division of the hepatic artery, along which vessel it also receives nerves from the cœliac plexus. The cystic veins empty themselves into the vena portæ.

The **cystic duct** is about an inch and a half in length (35 mm., Luschka), and only about $\frac{1}{12}$th of an inch wide (2·3 mm., Krause). It runs backwards, downwards, and to the left, and unites with the hepatic duct to form the common bile-duct.

The **common bile-duct**, *ductus communis choledochus*, about $\frac{1}{4}$ of an inch (5·6 mm. to 7·5 mm., Krause) in width, and nearly three inches (about 70 mm.) in length, conveys the bile into the duodenum. It passes downwards and backwards, continuing the course of the hepatic duct, between the layers of the gastro-hepatic omentum, in front of the vena portæ, and to the right of the hepatic artery. Passing behind the first part of the duodenum it reaches the descending portion and continues downwards on the inner and posterior aspect of that part of the intestine, covered by or included in the head of the pancreas, and for a short distance in contact with the right side of the pancreatic duct. Together with that duct, it then perforates the muscular wall of the duodenum, and, after running obliquely for three quarters of an inch between its coats, and forming an elevation beneath the mucous membrane, it becomes somewhat constricted, and opens by a common orifice with the pancreatic duct on the inner surface of the intestine, near the junction of the second and third portions of the duodenum, and three or four inches beyond the pylorus, as already described.

Liver in the Infant.—The liver is relatively much larger in the new-born child than in the adult. Indeed, at birth, it occupies nearly one half of the abdominal cavity. The left lobe, as compared with the right, is distinctly larger than in the adult, and often reaches to the left, so as to come in contact with the lateral wall of the abdomen on that side, presenting in this position a distinct left surface. In such cases Ballantyne describes the anterior surface as being more nearly quadrilateral than triangular. According to this authority, the anterior surface of the liver in the new-born infant corresponds in its vertical extent in the median plane with the last four dorsal and upper two lumbar vertebræ, and its lower border is within 2 cm. of the umbilicus. Its vertical extent increases from left to right, the lower edge of the right surface coming within 1 cm. or 1·5 cm. of the right iliac crest.

Varieties.—The liver is not subject to great or frequent deviation from its ordinary form and relations. It has been found without any division into lobes. On the other hand, Sœmmerring has recorded a case in which the adult liver was divided into twelve lobes, and similar cases of subdivided liver (resembling that of some animals) have been now and then observed by others. A detached portion, forming a sort of *accessory* liver, is occasionally found appended to the left extremity of the gland by a fold of peritoneum containing blood-vessels. The upper surface sometimes shows longitudinal furrows, which are occupied, when the organ is *in situ*, by folds of the diaphragm. These have been attributed to tight lacing, but, according to Turner, they are found almost as frequently in males as in females, and are probably congenital. Various cases have been described of unusual mobility of the liver in women with flaccid and often pendulous abdominal walls (see Landau, *Die Wanderleber und der Hängebauch der Frauen*, 1888).

The gall-bladder is occasionally wanting, in which case the hepatic duct is much dilated within the liver, or in some part of its course. Sometimes the gall-bladder is irregular in form, or is constricted across its middle, or, but much more rarely, it is partially divided in a longitudinal direction. Purser (Trans. Acad. Med., Ireland, Vol. V.) has recorded a case in which there were two distinct gall-bladders, each having a cystic duct which joined the hepatic duct. The gall-bladder has been found on the left side (Hochstetter, Arch. f. Anat., 1886) in subjects in which there was no general transposition of the thoracic and abdominal viscera. Direct communications by means of small ducts (named hepato-cystic), passing from the liver to the gall-bladder, exist regularly in various animals; and they are sometimes found, as an unusual formation, in the human subject.

The right and left divisions of the hepatic duct sometimes continue separate for some distance within the gastro-hepatic omentum. Lastly, the common bile-duct not unfrequently opens separately from the pancreatic duct into the duodenum.

STRUCTURE OF THE LIVER.

The liver is covered externally by a **serous coat** derived from the peritoneum. This, with its folds and so-called ligaments, has already received notice. In its general structure it resembles other serous membranes, but no stomata have as yet been described in it. Connecting the serous coat to the glandular substance, and also present where the serous coat is absent, is a layer of areolar tissue, which is described as the **areolar** or **fibrous coat** of the organ. Its inner surface is connected with the delicate areolar tissue which lies between the hepatic lobules. Opposite the transverse fissure, where it is greatly increased in amount, it invests the entering and issuing vessels and duct, forming for them a loose but strong sheath of areolar tissue, which surrounds all their branches as they ramify through the organ, becoming more and more delicate, until it becomes continuous with the areolar tissue between the lobules. To this investment of areolar tissue, which encloses the three vessels above mentioned, and their branches, the name **capsule of Glisson** has been applied, and the canals through the liver substance which are occupied by those vessels and their "capsule" have been termed **portal canals.** At the back of the liver, where there is no serous coat, the areolar coat is also

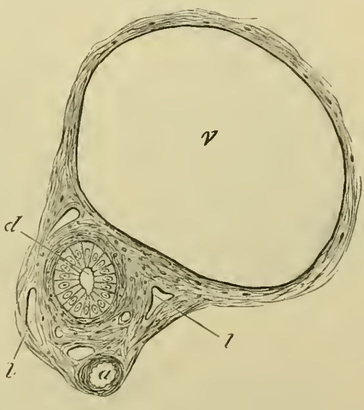


Fig. 150.—Section of a portal canal (E. A. S.). Magnified.

a, branch of hepatic artery; *v*, branch of portal vein; *d*, bile-duct; *l*, *l*, lymphatics in the areolar tissue of Glisson's capsule which encloses the vessels.

considerably thickened, and it here invests the hepatic veins as they issue from the organ to open into the vena cava inferior. These veins and their tributaries are also invested in their course through the liver by areolar tissue continuous with that of the areolar coat, but it is very small in amount, and binds the hepatic veins closely to the glandular substance, so that in section of these **hepatic canals** in the dead liver the vein always remains patent, whereas in section of the portal canals the looseness of the areolar tissue investing them, and the large relative amount of this tissue, enables the branches of the portal vein to collapse, and this is their usual condition when seen in section, if empty of blood. Both the portal and the hepatic canals conduct lymphatic vessels, which discharge their lymph into lymphatic glands, situated respectively at the transverse fissure and behind the organ.

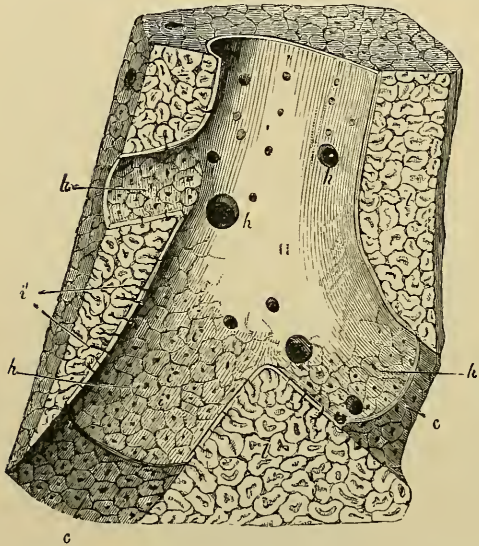
Hepatic lobules.—The proper substance of the liver, which has a mottled aspect when closely observed, is compact, but not very firm. It is easily cut or lacerated, and is not unfrequently ruptured during life from accidents in which other parts of the body have escaped injury. When the substance of the liver is torn, the broken surface is not smooth, but coarsely granular, the liver being composed of a multitude of small lobules (fig. 151), which vary from $\frac{1}{12}$th to $\frac{1}{24}$th of an inch in diameter (1—2 millimeters).

These lobules in some animals, as in the pig and camel, are completely isolated one from another by areolar tissue continuous with the fibrous coat of the liver, and with the capsule of Glisson; but in the human subject and in most animals, although very distinguishable, they are confluent in a part of their extent.

The lobules of the liver have, throughout its substance, in general the polyhedral form of irregularly compressed spheroids, but on the surface they are flattened and

angular. They are all compactly arranged around the sides of branches (*sublobular*) of the hepatic veins (fig. 151), each lobule resting, by a smooth surface or *base*, upon the vein, and being connected with it by a small venous trunklet (*intralobular*), which begins in the centre of the lobule, and passes out from the middle of its base, to end in the larger subjacent vessel. If one of the sublobular veins be opened (as in the figure), the bases of the lobules may be seen through the coats of the vein, which are here very thin, presenting a tesselated appearance, each little polygonal space representing the base of a lobule, and having in its centre a small spot, which is the mouth of the intralobular vein (*i*).

Each lobule consists of a mass of cells penetrated from the circumference to the



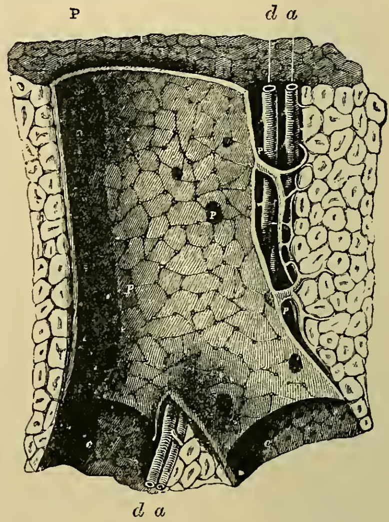


Fig. 151.—Section of a portion of liver passing longitudinally through a considerable hepatic vein, from the pig (after Kiernan). About 5 Diameters.

H, hepatic venous trunk, against which the sides of the lobules are applied ; *h*, *h*, *h*, three sublobular hepatic veins, on which the bases of the lobules rest, and through the coats of which they are seen as polygonal figures ; *i*, mouth of the intralobular veins, opening into the sublobular veins ; *i'*, intralobular veins shown passing up the centre of some divided lobules ; *c*, *c*, walls of the hepatic venous canal, with the polygonal bases of the lobules.

Fig. 152.—Longitudinal section of a portal canal, containing a portal vein, hepatic artery, and hepatic duct, from the pig (after Kiernan). About 5 diameters.

P, branch of vena portæ, situated in a portal canal, formed amongst the lobules of the liver ; *p*, *p*, larger branches of portal vein, giving off smaller ones named interlobular veins ; there are also seen within the large portal vein numerous orifices of interlobular veins arising directly from it ; *a*, hepatic artery ; *d*, biliary duct ; at *c*, *c*, the venous wall has been partially removed.

centre by a close network of blood-capillaries, as well as by the minute capillary commencements of the bile-ducts, with the intervention of little other tissue. For convenience of description, the disposition of the vessels of the liver may be considered first.

Blood-vessels.—The portal vein and hepatic artery, accompanied by the emerging biliary ducts, enter the liver at the transverse fissure. Within the liver the branches of these three vessels lie together in the portal canals.

The **portal vein** subdivides into branches which ramify between the lobules, anastomosing freely around them, and are named *interlobular* or *peripheral veins* (fig. 153, *p*). The branches of these pass into the lobules at their circumference,

and end in the capillary network, from which the *intralobular* or *central* veins take origin. Within the portal canals the branches of the portal vein receive small veins which are returning blood distributed by branches of the hepatic artery.

The **hepatic artery** terminates in three sets of branches, termed vaginal, capsular, and interlobular. The *vaginal* branches ramify within the portal canals,

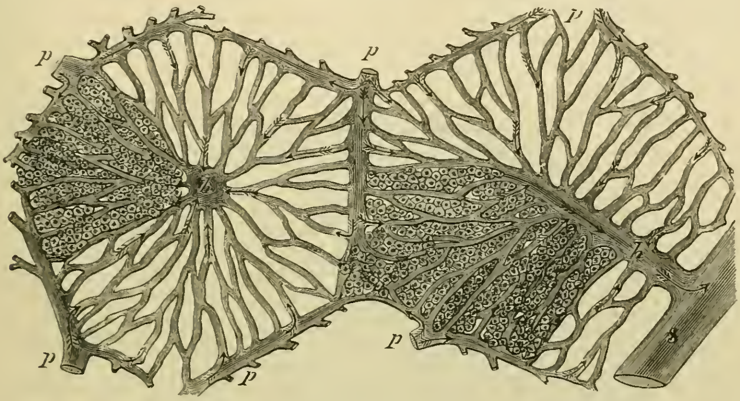


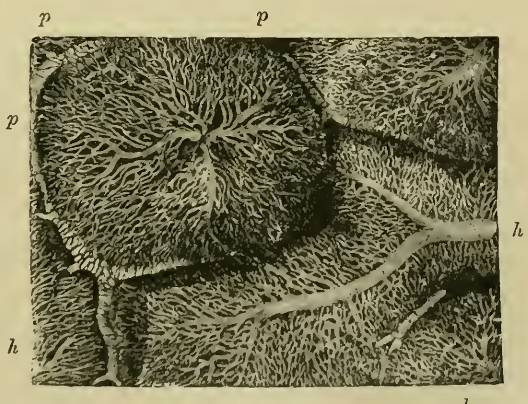
Fig. 153.—Diagrammatic representation of two hepatic lobules (E. A. S.)

The left-hand lobule is represented with the intralobular vein cut across; in the right-hand one the section takes the course of the intralobular vein. *p*, interlobular branches of the portal vein; *h*, intralobular branches of the hepatic veins; *s*, sublobular vein: *c*, capillaries of the lobules. The arrows indicate the direction of the course of the blood. The liver-cells are only represented in one part of each lobule.

supplying the walls of the ducts and vessels, and the accompanying connective tissue. The *capsular* branches appear on the surface of the liver spread out on the fibrous coat, accompanied by their veins. The *interlobular* branches accompany the interlobular veins, but are much smaller; they supply blood to the walls of these and

Fig. 154.—Capillary network of the lobules of the rabbit's liver (from Kölliker). About 40 Diameters.

The figure is taken from a very successful injection of the hepatic veins made by Harting; it shows nearly the whole of two lobules, and parts of three others: *p*, portal branches running in the interlobular spaces; *h*, hepatic veins radiating from the centre of the lobules.



the accompanying bile-ducts; it is doubtful if they transmit any blood directly to the capillary network of the lobules.

The **capillary network** of the lobules is very close, so that commonly the interval between two vessels is not greater than the diameter of two liver cells (figs. 153, 154, 155). Moreover, the vessels are comparatively large (0·01 mm.), and in specimens in which they have been filled with transparent injection, can be seen, not only to pass in a radiating manner, as before described, between the intra- and inter-lobular veins, but also in the human subject to be continued from one lobule to another.

The capillaries are accompanied by a small amount of fine connective tissue of a retiform or reticular character, the fibrils of which are densely felted, and when stained give the appearance of a close lattice-work. This is far better developed in some animals than in man. Characteristic of this tissue is the presence of a large number of stellate cells (Kupffer), which appear to be applied to the blood-capillaries. This reticular tissue occurs more abundantly at the centre and surfaces of the lobule, near the intralobular and interlobular veins, than elsewhere; it forms a delicate framework to the vascular and glandular structures. In the connective

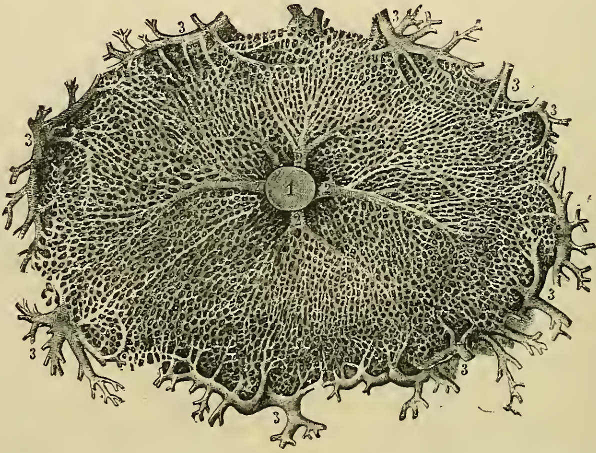


Fig. 155.—Cross section of a lobule of the human liver, in which the capillary network between the portal and hepatic veins has been fully injected (from Sappey). 60 diameters.

1, section of the intralobular or central vein; 2, its smaller branches collecting blood from the capillary network; 3, interlobular or peripheric branches of the vena portæ with their smaller ramifications passing inwards towards the capillary network in the substance of the lobule.

tissue accompanying the interlobular veins there are numerous granular connective tissue cells.

The **hepatic veins** commence in the centre of each lobule by the convergence of its capillaries into the single independent *intralobular* or *central vein* (figs. 153, *h*, and 155, 1), as already stated. These minute intralobular veins open at once into the sides of the adjacent *sublobular* veins (fig. 153, *s*), which are of various sizes, and join to form larger vessels, ending at length in hepatic venous trunks, which receive no intralobular veins. Lastly, these venous trunks, converging towards the posterior surface of the liver, and receiving in their course other sublobular veins, terminate in the vena cava inferior, as already described. In this course the hepatic veins and their successive ramifications are unaccompanied by any but lymphatic vessels. Their coats are thin; the sublobular branches adhere closely to the lobules, and even the larger trunks have but a slight areolar investment connecting them to the substance of the liver. Hence, as already explained, the divided ends of these veins are seen upon a section of the liver as simple open orifices, the thin wall of the vein being surrounded closely by the solid substance of the gland.

The hepatic cells.—The interstices between the blood-vessels are, as before said, almost entirely filled by the hepatic cells. These are of a compressed spheroidal or polyhedral form, having a mean diameter of from 0·017mm. to 0·022mm. They possess no cell membrane. Collectively they are yellowish, but, seen singly, are colourless, with a variable number of yellow or brown pigment granules in their

protoplasm. Their substance appears granular, and they contain each a clear round nucleus, with intra-nuclear network and one or two nucleoli. Sometimes two nuclei are to be found in a cell; this is frequently the case in the rabbit. In many cases, especially with a fatty diet, the cells are found to have large or small fat-globules in their interior; this fatty deposit is usually more abundant in the cells which are near the periphery than in those near the centre of the lobule. When isolated in the fresh condition they are said to exhibit slow changes of form. The liver-cells are packed between and around the vessels, and in sections made at right angles to the intralobular veins, appear as if radiating from the centre of the lobules towards their circumference. They form a continuous network, or sponge-work, the more obvious openings in which are the spaces occupied by the blood-capillaries. The walls of the latter are not everywhere in contact with the liver

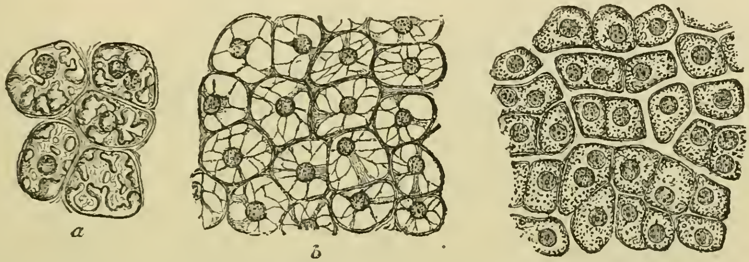


Fig. 156.—Hepatic cells from the liver of a dog 14 hours after a full meal. (Heidenhain.)

a, with glycogenic deposit; *b* and *c*, after its solution. In *c* the network of protoplasm which remains is finer than in *b*, and imparts a somewhat granular appearance to the cells. The external layer of the protoplasm contains no glycogen.

cells, but are separated from them in parts by a cleft-like lymphatic space, which is only imperfectly marked off by the flattened and stellate connective tissue cells before mentioned (p. 132).

The hepatic cells frequently contain glycogen, especially after a heavy meal of starchy matters. It occurs in globules or in irregular amorphous masses within them (Heidenhain), and when abundant reduces the protoplasm of the cell to the condition of an open network, which becomes very distinct after solution of the glycogen (fig. 156). When these masses of glycogen are not present the protoplasm exhibits, after hardening, a more finely reticulated appearance (Klein, Langley).

Commencement of the ducts.—When a thin section of the hardened tissue is examined under a high power of the microscope, minute apertures may occasionally be observed between the opposed sides of adjacent liver-cells. These are the sections of fine intercellular passages (*bile-canaliculi*), which form a close network (figs. 157, 158) between and around the individual cells, much finer and closer than the blood-capillary network, from the branches of which they run apart. These passages are the commencements of the biliary ducts, into which at the circumference of the lobule they open. They may be injected from the trunk of the bile-duct, at least in the outer parts of the lobule (fig. 157). It is uncertain whether they have a proper wall, or if they are merely channels grooved out between the hepatic cells.

To demonstrate the intercellular network throughout the whole extent of the lobules, Chrzonszczewsky employed a method of natural injection. He introduced a saturated watery solution of pure sulph-indigotate of soda, in repeated doses, into the circulation of dogs and sucking-pigs, by the jugular vein; and in an hour and

a half afterwards the animals were killed, and the blood-vessels either washed out with chloride of potassium, introduced by the portal vein, or were injected with gelatine and carmine. In specimens prepared in this way the fine network of bile-ducts throughout each lobule is filled with blue, while the intervening cells remain free from colour. By killing the animals sooner after the injection, the blue colouring matter was found within the hepatic cells, thus demonstrating that it was through their agency that the canals were filled. They may also be shown by the chromate of silver method.

From the observations of Pflüger and of Kupffer, it would appear that the

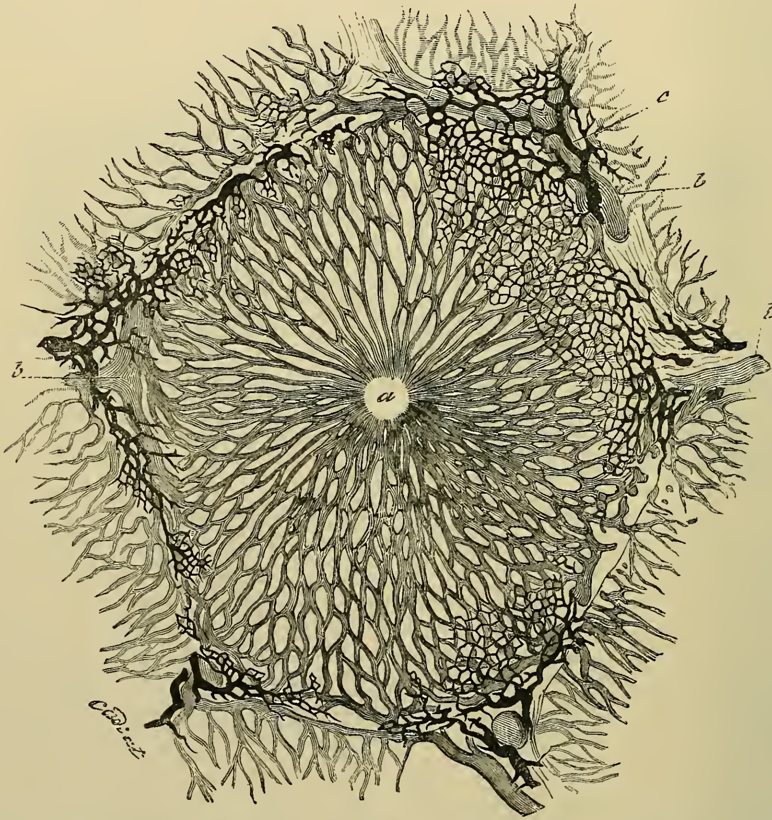


Fig. 157.—Section of a liver-lobule with the blood-vessels and ducts injected. (Cadiat.)

b, *b*, interlobular veins ; *a*, intralobular vein ; *c*, interlobular bile-ducts, with which the bile canaliculi from the lobule are connected. The canaliculi have only become injected in the peripheral parts of the lobule.

relation between the hepatic cells and the bile-canaliculi is even more intimate than has been generally supposed. For both by the methods of artificial and of natural injection, they have demonstrated the existence of vacuoles within the cells communicating by exceedingly minute intracellular channels with the adjoining bile-canaliculi (see fig. 159). These observations have since been confirmed by others, but it is not known whether the channels and vacuoles in question are permanent structures, or whether they are only formed at the moment of secretion.

In the lower vertebrates and in the embryos of birds and mammals the liver is a tubular gland, composed of branching tubules nearly filled with the glandular cells of the organ (fig. 160), and with narrow lumina (biliary canaliculi), directly

continuous with the ducts. The biliary canaliculi do not anastomose nor form a network in the embryo (fig. 160), and in some mammals, e.g., mouse, Retzius was unable to find evidence of a network, even in the adult state, although in others

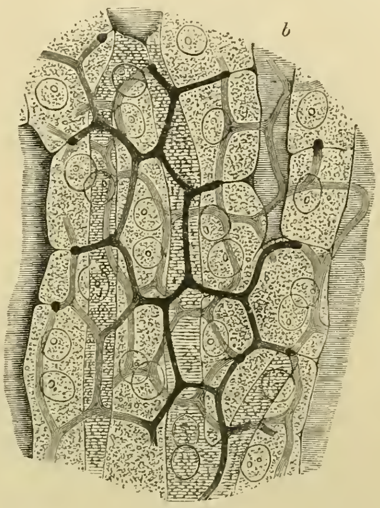


Fig. 158.—Section of rabbit's liver with the intercellular network of bile-canaliculi injected. Highly magnified (Hering).

Two or three layers of cells are represented; *b*, *b*, blood capillaries.

(dog, man) it is sufficiently obvious. In all animals the bile-canaliculi are separated by at least a portion of a liver-cell from the nearest blood capillaries.

A different account of the structure of the liver of the lower vertebrata and of the embryo bird and mammal is given by Shore and Jones (Journ. of Physiology, vol. x.).

Structure of the ducts.—The minute ramifications between the lobules have walls composed of fibrillar connective tissue, within which is a basement membrane, and a lining of short columnar epithelium. According to Heidenhain they also possess both longitudinally and circularly disposed muscular cells in their wall. As they pass into the lobules, the columnar epithelium becomes shorter and flatter, the tube at the same time branching both laterally and terminally, and becoming much reduced in size, so that only a very small lumen is left. The basement membrane is no longer complete, and the intercellular bile passages open

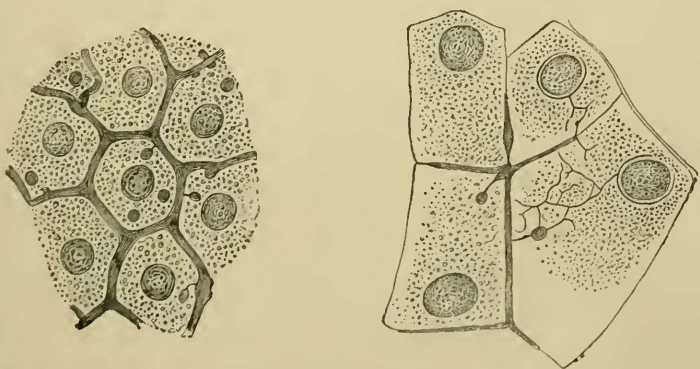


Fig. 159.—Sketches illustrating the mode of commencement of the bile-canaliculi within the liver-cells (Heidenhain after Kupffer).

A. Canaliculi of the rabbit's liver artificially injected from the hepatic duct with Berlin blue solution. The intercellular canaliculi are seen to give off minute twigs, which penetrate into the liver-cells, and there terminate in vacuole-like enlargements.

B. From a frog's liver naturally injected with sulph-indigotate of soda. A similar appearance is obtained, but the communicating twigs are ramified.

directly into the minute ducts, the hepatic cells abutting against the flattened epithelium of the latter.

In the portal canals, where they are somewhat larger, the ducts present numerous openings on the inner surface, which are scattered irregularly in the larger ducts, but in the subdivisions are arranged in two longitudinal rows, one at each side of

the vessel. These openings were formerly supposed to be the orifices of mucous glands; but, while the main ducts are studded with true mucous glands of lobulated form and with minute orifices, the openings now referred to belong to saccular and tubular recesses, which are often branched and anastomosing, and may be beset all over with cæcal projections (Theile). The larger bile-ducts have areolar coats, containing abundant elastic tissue, and a certain amount of plain muscular tissue disposed both longitudinally and circularly. They are lined with columnar epithelium.

In the duplicature of peritoneum forming the left lateral ligament of the liver, and also in the two fibrous bands which sometimes bridge over the fossa for the vena cava and the fissure of the umbilical vein, there have been found biliary ducts of considerable size which are not surrounded with lobules. These *aberrant ducts*, as they are called, were described by Ferrein, and afterwards by Kiernan; they anastomose together in form of a network, and are accompanied by branches of the vena portæ, hepatic artery, and hepatic vein. They represent portions of hepatic

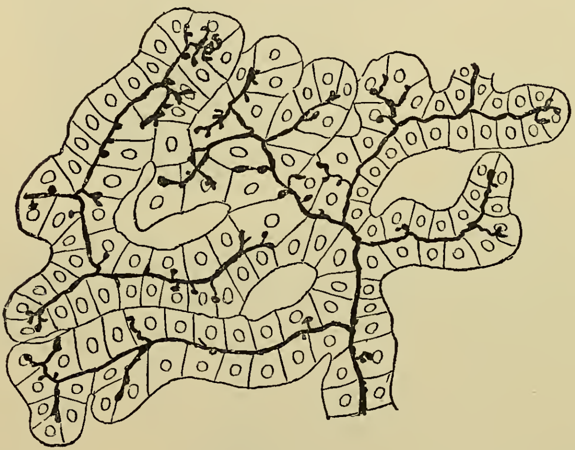


Fig. 160.—From a chromate of silver preparation of the liver of a six months' fœtus. (G. Retzius.)

The bile-canaliculi are represented black. It is seen that at this stage of development they do not anastomose. They appear to give minute offsets, which end between and within the liver-cells in small enlargements.

substance which were present at an early period of development, but have subsequently become atrophied.

Lymphatics of the liver. — Lymphatics are seen in the prolongations of Glisson's capsule between the lobules (*interlobular lymphatics*), where they accompany the blood-vessels, and in some cases surround and enclose them. They originate from the lymphatic spaces around the capillaries of the lobules (p. 133). They unite into larger vessels, which run along the portal canals (fig. 150, *l l*), and emerge at the portal fissure. Other lymphatic vessels accompany the branches of the *hepatic* veins, also conveying lymph from the perivascular lymphatics of the lobules. There is further a close *subperitoneal plexus* on the surface of the organ, which on the upper surface communicates, through the ligaments of the liver, with the thoracic lymphatics, and on the under surface with the lymphatics of Glisson's capsule.

In the pig's liver lymphoid follicles have been noticed by Kisselew and Chrzonszczewsky, in connection with the interlobular lymphatics.

Nerves of the liver.—The liver receives nerves from the left pneumogastric and from the solar plexus of the sympathetic. The branches of the pneumogastric reach the organ between the two layers of the small omentum and enter at the portal fissure. The sympathetic branches also enter the portal fissure, accompanying the hepatic artery: some branches also accompany the portal vein. The terminations of the nerves within the liver have been investigated by Berkeley, who describes them as ending in fine terminal arborizations, showing varicosities, especially at their extreme endings, and as being distributed to the walls of the blood-vessels and biliary ducts, and also between the hepatic cells of the lobules. According to this author, they follow the course of the biliary canaliculi. Korolkow has studied the nerve-endings in the liver of the pigeon by the methylene

blue method. He describes the nerves which enter the liver and accompany the vessels and ducts to the intervals between the lobules as both medullated and non-medullated. Of these, the latter are distributed almost exclusively to the arteries and veins, whereas the former enter the lobules, and, losing their medullary sheaths, run at first along the trabeculæ of hepatic cells, and finally end by ramifying between and over the cells (fig. 161).

Structure of the Gall-bladder.—Besides the peritoneal investment and the mucous lining, the gall-bladder possesses an intermediate muscular and connective tissue coat, of considerable strength. This consists mainly of bands of dense shining white fibres, which interlace in all directions. Intermingled with these are plain

Fig. 161.—Plexus of nerve-fibrils within a hepatic lobule of the pigeon; methylene blue method. (Korolkow.)

a a, axis-cylinders of nerve-fibres, passing between the cell-trabeculæ of the lobule, *c*; *b b*, fibrils ramifying over the cells of the trabeculæ.

muscular fibres, which have principally a longitudinal direction, but some run transversely. This coat forms the framework of the organ, and supports the larger blood-vessels and lymphatics. The nerves form a gangliated plexus within it; partly also immediately beneath the serous coat (L. Gerlach).

The **mucous membrane** which after death is generally strongly tinged with bile, is elevated upon its inner surface into very numerous small ridges, which, uniting together into meshes, leave between them depressions of different sizes, and of various polygonal forms. This gives the interior of the gall-bladder an alveolar aspect, similar to what is seen on a smaller scale in the vesiculæ seminales. These alveolar intervals become smaller towards the fundus and neck of the gall-bladder, and at the bottom of the larger ones other minute depressions, which may be seen with a simple lens, lead into numerous mucous recesses. The whole of the mucous membrane is covered by columnar epithelium, and it secretes an abundance of viscid mucus. The blood-vessels form a close network near the surface of the mucous membrane, and there is also a fine lymphatic plexus in the mucous membrane, communicating with a network of larger vessels in the serous coat

At the places where the neck of the gall-bladder curves on itself there are strong folds of its mucous and areolar coats projecting into the interior.

In the *cystic duct* the mucous membrane is elevated internally in a similar manner into a series of crescentic folds, which are arranged in an oblique direction, and succeed closely to each other, so as to present very much the appearance of a continuous spiral valve. When distended, the outer surface of the duct appears to be indented in the situation of these folds, and dilated or swollen in the intervals so as to present an irregularly sacculated or twisted appearance. In the structure of its wall the cystic duct resembles the gall-bladder.

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THE PANCREAS.

The pancreas (fig. 162) is a long gland of a reddish cream colour and irregularly prismatic shape, which lies across the posterior wall of the abdomen, behind the stomach, and opposite the first and second lumbar vertebræ. Its right end is the larger and is termed the *head;* from this arises a short and slightly constricted *neck*, which connects the head with the *body*. The body passes to the left, its free extremity or *tail* touching the spleen.

The pancreas varies considerably, in different cases, in its size and weight. It is usually 5 or 6 inches (120—150 mm.) long, and from half an inch to an inch in thickness. The

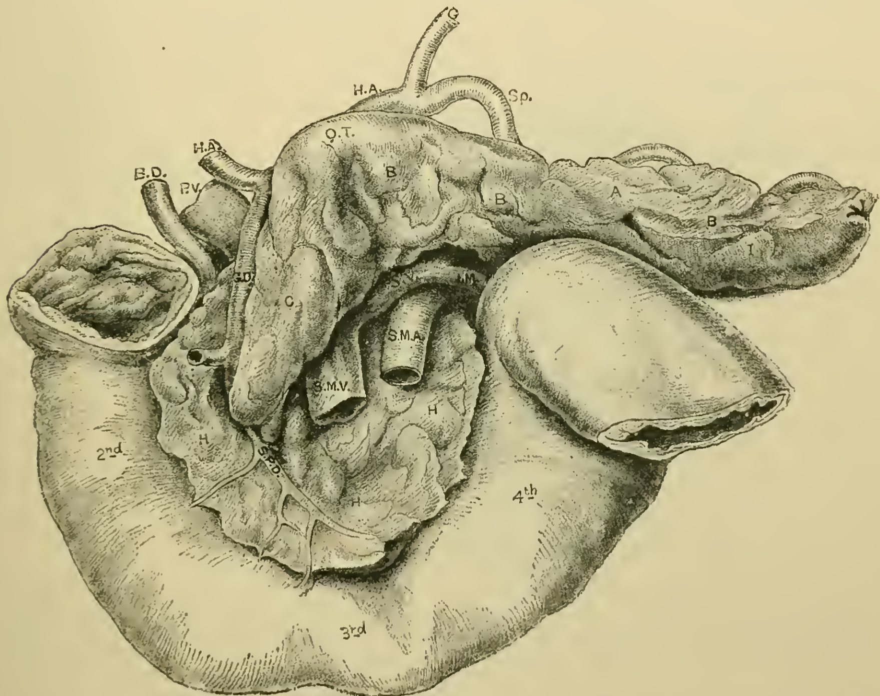

Fig. 162.—Anterior aspect of the pancreas, &c., drawn by G. C. R. Harbinson, from a specimen prepared by hardening the abdominal viscera in situ by the injection of a 1 p.c. solution of chromic acid. (J. S.)

H.H.H., head of pancreas; C., its neck; B.B., its body; A., anterior surface of the body; I., its inferior surface; O.T., omental tuberosity near right end of body; 2nd, 3rd, 4th, corresponding parts of the duodenum; J., jejunum; H.A., hepatic artery; G., gastric artery; S.P., splenic artery; G.D., gastro-duodenal artery; S.P.D., superior pancreatico-duodenal artery; S.V., splenic vein; I.M., inferior mesenteric vein; S.M.V., superior mesenteric vein; P.V., portal vein; B.D., bile duct.

weight of the gland, according to Krause and Clendenning, is usually from $2\frac{1}{4}$ to $3\frac{1}{2}$ oz. (66 to 102 grammes): but Meckel has noted it as high as 6 oz., and Sœmmerring as low as $1\frac{1}{2}$ oz. Its specific gravity is 1·046.

The head (fig. 162, H) of the pancreas forms a disc-shaped mass flattened from before backwards, and lying in the concavity formed by the second, third, and fourth parts of the duodenum, to which it is closely united. The superior mesenteric vessels are in contact with the anterior surface near its left border, while near its lower end it is crossed by the transverse colon and its meso-colon. The superior and inferior pancreatico-duodenal vessels pass down in front of the head a short

distance from its right and left borders respectively. Posteriorly it lies upon the inferior vena cava, the left renal vein and the aorta. The common bile duct passes down behind it, and is generally received into a groove or canal in its substance.

The *neck* of the pancreas (fig. 162, C) is about an inch long. It springs from the upper part of the anterior surface of the head and turns upwards, forwards, and to the left to join the body. In its course it passes in front of the termination of the superior mesenteric vein and the commencement of the vena portæ. At its attachment to the head it is grooved on its right side by the gastro-duodenal and superior pancreatico-duodenal arteries. The first part of the duodenum lies against its

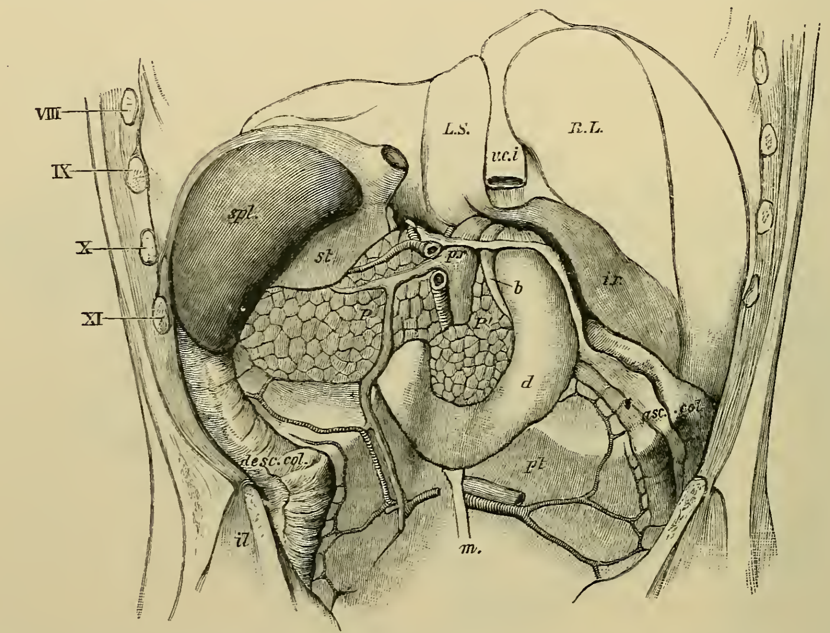

Fig. 163.—View of the abdominal viscera from behind, after removal of the spinal column, the whole of the posterior wall of the abdomen and the kidneys and supra-renal capsules, the peritoneum being left (this and the next figure are taken from Prof. His' models). $\frac{1}{3}$

P, pancreas ; *P'*, its head : *d*, duodenum ; *st*, stomach ; *spl*, spleen ; *R.L.*, right lobe of the liver ; *L.S.*, Spigelian lobe ; *v.c.i.*, vena cava inferior ; *p.r.*, portal vein ; *b*, common bile duct ; *i.r.*, impression for the right kidney on the posterior surface of the liver ; the situation of the two kidneys is well shown by the corresponding impressions in the cast : *asc. col.*, *desc. col.*, ascending and descending colon ; *pt*, back of the peritoneum ; *m*, line of attachment of the mesentery ; VIII, IX, X, XI, the corresponding ribs ; *il*, ilium.

anterior and right aspect, and the pylorus often touches it when the stomach is distended.

The *body* and *tail* together (fig. 162, B) are four or five inches long. After crossing from the right side in front of the aorta the body curves backwards in its course to the left, and close to the spleen the tail turns sharply upwards and backwards. The body is prismatic in form and has three surfaces, anterior, posterior, and inferior. The inferior surface is narrow but better marked on the left than on the right side. The surfaces, like those of the liver, are moulded to the adjacent organs.

The anterior surface is concave, looks upwards as well as forwards, and is covered by the stomach, the lesser sac of the peritoneum intervening. At its right extremity it often forms a well-marked prominence called the *omental tuberosity* (His).

The posterior surface lies in front of the aorta, the origin of the superior mesenteric artery, the pillars of the diaphragm, the splenic vein, the left kidney and its vessels, and the left suprarenal capsule.

The inferior surface is narrow and rests upon the duodeno-jejunal flexure, and frequently also upon some convolutions of the jejunum and upon the transverse colon near its left end.

The superior border lies in relation with the cœliac axis, the hepatic branch of this trunk passing to the right just above it, while on the left side the splenic artery in its tortuous course to the spleen grooves it.

At the anterior border the two layers of the transverse meso-colon separate, the anterior layer ascending in relation with the anterior surface of the pancreas, whilst the posterior layer passes backwards in contact with the inferior surface. The posterior surface is thus devoid of peritoneum.

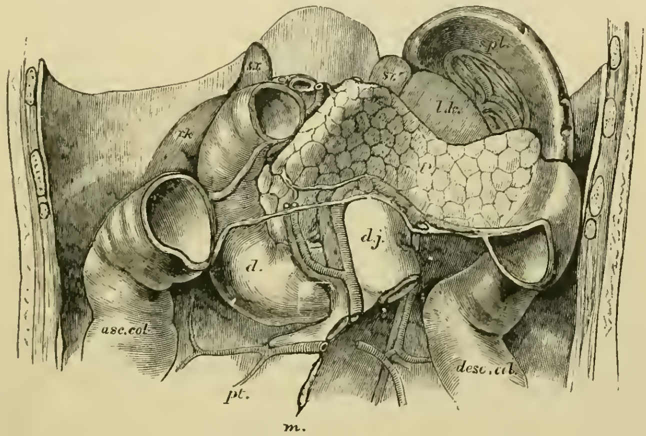

Fig. 164.—The pancreas and adjoining viscera from before. $\frac{1}{3}$

The liver, the stomach, the greater part of the small intestine, and the transverse colon have been removed. *P*, pancreas ; *d*, duodenum ; *d.j.*, duodeno-jejunal flexure ; above the duodenum, and between it and the head of the pancreas are seen the bile-duct, portal vein, and hepatic artery ; *asc. col.*, *desc. col.*, ascending and descending colon ; *spl.*, spleen ; *r.k.*, *l.k.*, right and left kidneys ; *s.r.*, *s.r'*, right and left suprarenal capsules ; *pt*, peritoneum at the back of the abdominal cavity ; *m*, line of reflection of the mesentery ; the line of reflection of the transverse mesocolon is seen along the lower edge of the pancreas and crossing the duodenum.

The tail of the pancreas is in contact with the lower part of the inner surface of the spleen.

The principal excretory duct, called the *pancreatic duct* or *canal of Wirsung*, runs through the entire length of the gland from left to right, buried entirely in its substance. Commencing by the union of the small ducts derived from the groups of lobules composing the tail of the pancreas, and receiving in succession at various angles and from all sides the ducts from the body of the gland, the canal of Wirsung pursues a nearly straight course in the axis of the gland until it reaches the neck. Here it turns obliquely downwards, backwards, and to the right through the neck and head, gradually approaching the posterior surface of the latter. Near its termination it comes in contact with the left side of the common bile duct, which it accompanies to the second part of the duodenum. As it traverses the head of the pancreas it is joined by numerous branches, one of which coming from the lower part of the head is larger than the others. The bile and pancreatic ducts placed side by side, pass very obliquely through the muscular and areolar coats of the

intestine, and terminate, as already described, on its internal surface, by a common orifice, situated near the junction of the second and third portions of the duodenum, between three and four inches below the pylorus. The pancreatic duct, with its branches, is readily distinguished within the glandular substance, by the very white appearance of its thin fibrous walls. Its widest part, near the duodenum, is from $\frac{1}{12}$th to $\frac{1}{9}$th of an inch in diameter, or nearly the size of an ordinary quill. It is lined by a remarkably thin and smooth membrane, which near the termination of the duct may present a few scattered recesses.

Varieties of pancreas and its ducts.—Symington (Journal of Anatomy and Physiology, 1885) described a case in which the upper part of the second portion of the duodenum was encircled by a ring of pancreatic tissue. A somewhat similar case has been recorded by Genersich (Verhandl. x. Internat. Med. Congress, 1890). The tail of the pancreas is sometimes bifid; and the part of the head lying behind the mesenteric vessels may be separate from the remainder of the gland, and form what is called the *lesser pancreas.*

Various examples of an accessory pancreas have been described. They occur most frequently in the wall of the upper part of the jejunum, more rarely in the wall of the stomach (see Zenker, *Nebenpancreas in der Darmwand*, Arch. f. path. Anat., Bd. xxi.).

Accessory duct, or *duct of Santorini.* Occasionally the main duct gives off at the neck an accessory duct, which passes to the right and opens into the duodenum about an inch above the common opening of the bile and main pancreatic ducts. This accessory duct is occasionally found of large size, and evidently serving as the principal channel for the passage of the pancreatic secretion into the duodenum, the lower part of the duct of Wirsung being small. On the other hand the accessory duct may not open into the duodenum, but terminate in the upper and right part of the head in small branches. In such cases its contents must pass from right to left, and be discharged into the duct of Wirsung.

Schirmer (*Beitrag zur Geschichte und Anat. des Pancreas*, Basel, 1893), has investigated the arrangement of the ducts of the pancreas in 105 specimens. In fifty-six of these the duct of Santorini arose from the main duct, and opened into the duodenum upon a papilla situated above the common orifice of the bile and pancreatic ducts. In nineteen the duct of Santorini, although well developed, did not open into the duodenum. In four there was only one pancreatic duct, and that the upper, the common bile-duct opening by itself lower down. In none of his specimens did he meet with an example of an arrangement described by Claude Bernard, in which there were two ducts running throughout the whole length of the gland.

The variations of the pancreatic ducts are of interest in connection with the mode of development of the pancreas. From the observations of Zimmermann and Hamburger it appears that in the human subject the pancreas is formed from two distinct outgrowths from the wall of the duodenum. One of these, the smaller, is in close relation with the duodenal end of the common bile-duct; the other, which is situated nearer the pylorus, is much larger, and forms the greater part of the pancreas. About the sixth week of embryonic life the two processes join, and their contained ducts subsequently communicate with one another. The portion of the upper duct on the duodenal side of the point of union grows less rapidly than the lower duct. It becomes the duct of Santorini, while the lower duct, with the peripheral portion of the upper one, forms the main channel for the pancreatic secretion, and is generally known in the adult as the main pancreatic duct, or canal of Wirsung.

Structure.—The pancreas belongs to the class of acino-tubular glands. In its general characters it closely resembles the salivary glands, but it is somewhat looser and softer in its texture than those organs, the lobes and lobules being less compactly arranged.

The ducts are lined with a simple layer of long columnar epithelium, the cells becoming shorter and more cubical in the smaller ducts. They do not exhibit any well-marked longitudinal striation like that met with in the duct-cells of some of the salivary glands. The ultimate branches of the ducts which are connected with the alveoli (*intercalary ducts*), are much narrowed, and are lined with flattened cells, looking spindle-shaped in optical section. The alveoli of the gland are distinctly tubular, and somewhat convoluted. In the inactive condition of the gland, and during the earlier stages of activity, the alveoli are almost completely occupied by the secreting cells, scarcely any lumen being visible. Moreover the middle of the

alveolus is in the dog and some other animals occupied by spindle-shaped cells (*centro-acinar cells*, fig. 165) which according to Langerhans are continuous with the epithelium-cells of the intercalary ducts.

The secreting cells of the pancreas have a very characteristic appearance. They

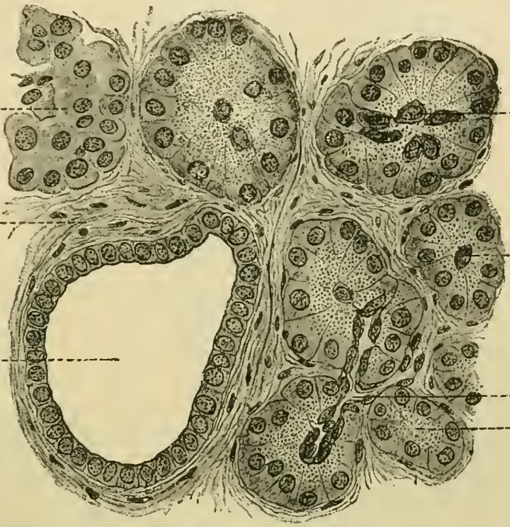

Fig. 165.—Section of human pancreas. (Böhm and Davidoff.) $\frac{450}{1}$.

frequently, if not constantly, contain, besides the ordinary nucleus, a *paranucleus* (Nebenkern), a spherical mass, staining more readily than the rest of the protoplasm, and said to be formed by extrusion of material from the nucleus (Gaule, Nicolaides). In shape they are columnar, in some parts approaching the polygonal form, and they show very distinctly, even in the loaded condition of the gland, two

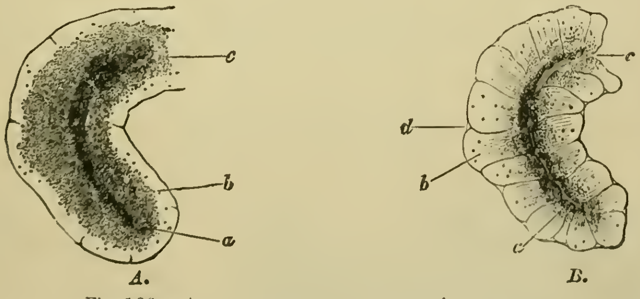

Fig. 166.—An alveolus of the rabbit's pancreas.

A., during rest, the cells loaded with granules, and the inner zone, *a*, large, and the outer zone, *b*, narrow.

B., after activity, the inner zone small, and the outer zone large and distinctly striated. The cell outlines are also now visible. *c*, lumen of alveolus; *d*, basement membrane. (Kühne and Lea.)

parts or zones; an inner granular zone next the lumen, and an outer clear and finely-striated zone next the basement membrane (figs. 165 and 166).

When the gland is stimulated to activity the cells at first enlarge and bulge the basement membrane; subsequently the granules of the inner zone become fewer in number and aggregated near the lumen, and the outer clear zone extends over the greater part of the cell (Heidenhain, Kühne and Lea (fig. 166)). It is stated by

Ogata that these zymogen granules are formed from the paranucleus, but the statement requires confirmation.

A

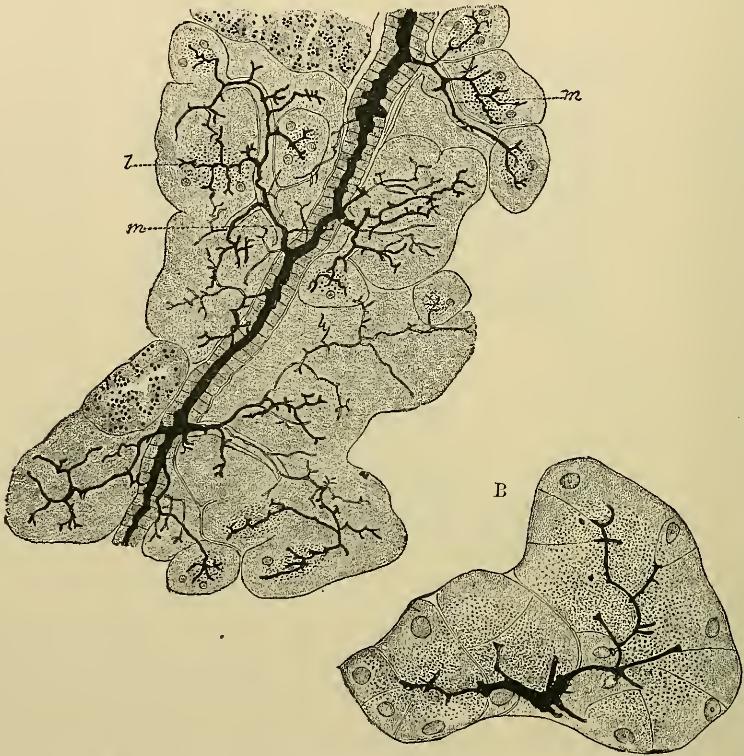

Fig. 167.—Origin of the ducts of the pancreas, as shown by the chromate of silver method. (E. Müller.)

A, duct cut longitudinally, lined by columnar epithelium giving off laterally the intercalary or lobular ductules, *m*, to the alveoli, *l*. The manner in which these commence within the alveoli is shown under a higher power in B.

Various observers, after forcing injections into the alveoli of the pancreas backwards from the duct, have seen fine intercellular canaliculi, comparable to those

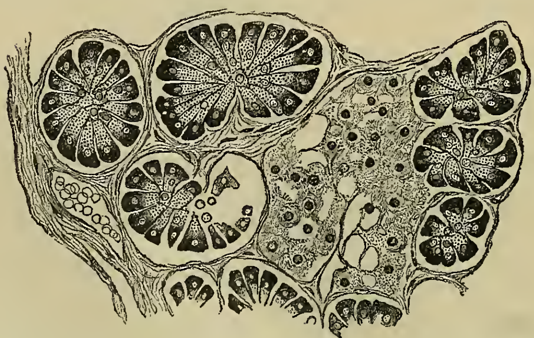

Fig. 168.—Section of pancreas of armadillo, showing several alveoli and one of the inter-alveolar cell-islets. (V. D. Harris.)

The alveolar cells are much more elongated here than in man and in most animals.

of the liver, passing from the lumen of an alveolus between the secreting cells. These can also be shown by the use of Golgi silver chromate method (fig. 167, A), and with a high magnifying power, the canaliculi can be seen penetrating not only between the cells of the alveoli, but even into the interior of the individual cells (fig. 167, B).

Connective tissue; interalveolar cell-islets.—The connective tissue of the gland, afterforming a sort of external investment, penetrates between its lobes or lobules conveying the blood-vessels to all parts. They are not, however, everywhere equally numerous, for some acini are not surrounded by the capillary network. On the other hand, in certain parts of the interalveolar tissue collections of small cells (*interalveolar cell-islets*, figs. 165, 168) are met with, which are permeated with a very close network of large convoluted capillaries. The cells in question are like the cells met with in the carotid and coccygeal glands, but their meaning is entirely unknown. They are very characteristic of the pancreas, being apparently always present in it.

Blood-vessels, lymphatics, and nerves.—The **arteries** of the pancreas are derived from the *splenic* and *hepatic divisions of the cœliac axis*, and from the *inferior pancreatico-duodenal branch of the superior mesenteric*. Its **veins** are tributaries of the *splenic* and *superior mesenteric*, and therefore belong to the portal system. The **lymphatics** pass to some of the neighbouring cœliac glands. Their arrangement within the pancreas is similar to that found in the salivary glands.

The **nerves** are derived from the solar plexus, and accompany the arteries to the organ. They are almost exclusively non-medullated and have minute ganglia on them as they traverse the gland. Besides these ganglia, small cells, apparently of nervous nature, are found upon the nerves, near their distribution to the epithelium-cells of the alveoli, over and between which they ultimately ramify.

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ORGANS OF RESPIRATION AND VOICE.

BY E. A. SCHÄFER AND J. SYMINGTON.

THE organs of respiration and voice comprise the *larynx*, *trachea*, and *bronchi*, and the *lungs*, with their serous investments, named the *pleuræ*.

The respiratory organs are developed as a median outgrowth from the ventral wall of the fore-gut, and this primitive connection between the alimentary canal and the respiratory apparatus is maintained in the adult, the upper end of the air-passage opening on the anterior wall of the pharynx. Below, this median air-tube divides into two lateral branches, one for each lung, while its upper part is modified to form the organ of voice. In the majority of mammals the windpipe opens above into the nasal part of the pharynx, the anterior boundary of the orifice (the epiglottis) projecting upwards behind the soft palate. This is not the case, however, in the human subject, either during intra-uterine or extra-uterine life.

THE LARYNX, OR ORGAN OF VOICE.

The **larynx** is placed at the upper and fore part of the neck, where it forms a considerable prominence in the middle line. It lies between the large vessels of the neck, and below the tongue and hyoid bone. It is covered in front by the skin and cervical fascia along the middle line, and on each side also by the sterno-hyoid, sterno-thyroid, and thyro-hyoid muscles, by the upper end of the lateral lobe of the thyroid body, and by a small part of the inferior constrictor of the pharynx. Behind, it is separated from the 4th, 5th and 6th cervical vertebræ by the laryngeal part of the pharynx and the prevertebral muscles. Above, it opens into the cavity of the pharynx, and below, into that of the trachea.

Its dimensions, according to Sappey, are, on an average of eight males and eight females, as follows :—

Vertical diameter, measured from the upper border of the thyroid cartilage to the lower border of the cricoid, 44 mm. in the male and 36 in the female ;

Transverse diameter, represented by the distance between the posterior borders of the thyroid cartilage, 43 mm. in the male and 41 in the female ;

Antero-posterior diameter, measured from the most prominent part of the anterior border of the thyroid cartilage to a line uniting its posterior borders, 36 mm. in the male and 26 in the female.

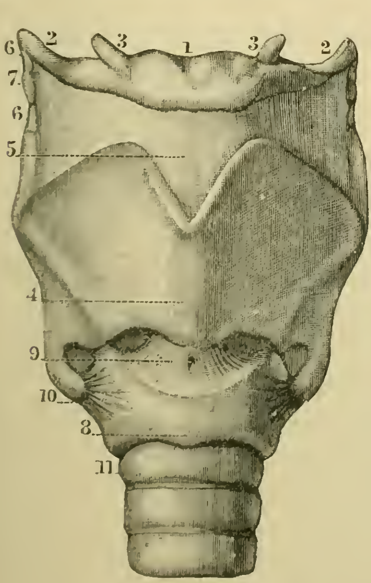
The larynx consists of a framework of cartilages, articulated together, and connected by elastic membranes or ligaments, two of which, projecting into the interior of the cavity, are named the *true vocal cords*, being more immediately concerned in the production of the voice. It possesses special muscles, which move the cartilages one upon another, and modify its form and the tension of its ligaments, and it is lined by a mucous membrane, continuous above with the mucous membrane of the pharynx and below with that of the trachea.

CARTILAGES OF THE LARYNX.

The cartilages of the larynx (figs. 169A, and 169B) consist of three single and symmetrical pieces, named respectively the *thyroid cartilage*, the *cricoid cartilage*, and the *cartilage of the epiglottis*, and of three pairs, namely, the two *arytenoid*

cartilages, the *cornicula laryngis*, and the *cuneiform cartilages.* In all there are nine distinct pieces, but the cornicula and cuneiform cartilages are very small. Only the thyroid and cricoid cartilages are visible on the front and sides of the larynx; the back of the cricoid cartilage, surmounted by the arytenoid cartilages, and these again by the cornicula, are seen behind; whilst the epiglottis is situated in front of, and the cuneiform cartilages on each side of, the upper opening.

The **thyroid cartilage,** the largest, consists of two flat lateral plates, which are united in front at the *isthmus*, and form an angle of about 90° with one another like the letter V, most prominent at the upper part. This angular projection is subcutaneous, and is much more marked in the male than in the female, being named in the former the *pomum Adami.* The two symmetrical halves, named the *alæ*, are somewhat quadrilateral in form. Of each half the anterior border is the shortest, the pomum Adami being surmounted by a deep *thyroid notch* (see fig. 169A). The free posterior border is thickened and vertical, and is prolonged



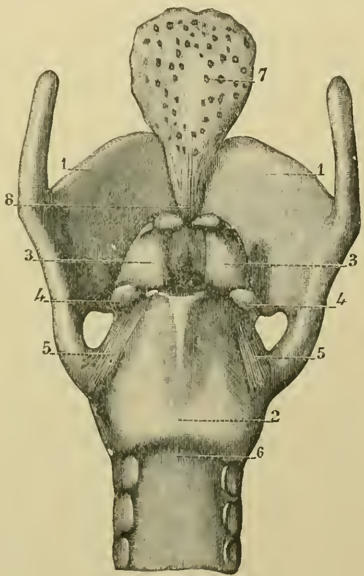


Fig. 169A.—Front view of the laryngeal cartilages and ligaments. (Sappey.)

1, hyoid bone; 2, its large cornua; 3, its small cornua; 4, thyroid cartilage; 5, thyro-hyoid membrane; 6, lateral thyro-hyoid ligament, containing the *cartilago triticea*, 7; 8, cricoid cartilage; 9, crico-thyroid membrane; 10, lateral crico-thyroid ligaments; 11, uppermost ring of trachea.

Fig. 169B.—Back view of the laryngeal cartilages and ligaments. (Sappey.)

1, thyroid cartilage; 2, cricoid cartilage; 3, arytenoid cartilages; 4, their muscular processes; 5, a ligament better marked than usual, connecting the lower cornu of the thyroid with the back of the cricoid cartilage; 6, upper ring of the trachea; 7, epiglottis; 8, ligament connecting it to the angle of the thyroid cartilage. The cornicula are seen surmounting the arytenoid cartilages.

upwards and downwards into two processes or *cornua;* it gives attachment to the stylo-pharyngeus and palato-pharyngeus muscles. The upper and lower borders have each a well-marked concavity close to the cornu; otherwise the upper is convex, and the lower nearly straight. The flattened external surface of each ala is marked by an indistinct oblique line or ridge (fig. 169A), which, commencing above at the posterior part of the superior border in a slight prominence called the *superior tubercle*, passes downwards and slightly forward, and ends at the lower border in an *inferior tubercle*, so as to mark off the anterior three-fourths of the surface from the remainder. This line gives attachment below to the sterno-thyroid, and

above to the thyro-hyoid muscle, whilst the small smooth surface behind it gives origin to part of the inferior constrictor of the pharynx, and affords attachment, by means of areolar tissue, to the thyroid body. On their internal surfaces the alæ are smooth and slightly concave. Of the four cornua, all of which bend inwards, the two *superior* or *great* cornua (fig. 169), pass upwards with sometimes a slight backward curve, and terminate each by a blunt extremity, which is connected, by means of the lateral thyro-hyoid ligament, to the tip of the corresponding great cornu of the hyoid bone (fig. 169A, 2). The *inferior* or *smaller* cornua, which are somewhat thicker but shorter, are directed slightly forwards, and, on the inner aspect of the tip, show a smooth surface, for articulation with a prominence on the side of the cricoid cartilage.

Occasionally there is a foramen in the ala of the thyroid cartilage situated near the upper part of its posterior border; an abnormal branch of the superior laryngeal artery passes through it. In the infant the isthmus of the thyroid cartilage differs from the two alæ in being less opaque and more flexible.

The **cricoid cartilage** (fig. 169A, 8), which is shaped like a signet ring, is thicker and stronger than the thyroid. It is deep behind (fig. 169B, 2), where it is expanded into a squarish plate or lamina, measuring in the male about an inch from above downwards; but in front it forms a narrow ring or arch, with a vertical measurement of only one-fourth or one-fifth of an inch. Corresponding with this, the *superior border*, which is markedly elevated behind, descends with a deep concavity in front below the thyroid cartilage; while the *inferior border* is horizontal, and connected by membrane to the first ring of the trachea. The posterior elevated part of the upper border is slightly depressed in the middle line, and on the sides of this depression are the elongated oval facets for articulation with the arytenoid cartilages. These facets are slightly convex, and they look outwards as well as upwards. The *external surface* of the cartilage is convex and smooth in front and at the sides, where it affords attachment to the crico-thyroid muscles, and behind these to the inferior constrictors of the pharynx; in the middle line posteriorly is a slight vertical ridge to which some of the longitudinal fibres of the œsophagus are attached. On each side of this ridge is a broad depression occupied by the posterior crico-arytenoid muscle, outside which is a small flat, oval, and slightly raised surface for articulation with the inferior cornu of the thyroid cartilage. The *internal surface* is covered throughout by the mucous membrane of the larynx. At its lower border the cricoid is circular, but higher up the cartilage is somewhat compressed laterally, so that the passage through it is here elliptical.

The **arytenoid cartilages** (fig. 169B, 3) are two in number, and symmetrical in form and position. They may be compared in shape to irregular three-sided pyramids, and they rest by their bases on the posterior and highest part of the cricoid cartilage, while their somewhat curved apices approach one another. Each is about half an inch high and one quarter of an inch wide. Of the three faces the *posterior* is broad, triangular, and concave from above downwards, lodging part of the arytenoid muscle. The *anterior*, or *external*, has a transverse ridge situated at about the junction of its lower and middle thirds; above and below this the surface is concave. The false vocal cord is attached near the inner end of the ridge, and the thyro-arytenoideus is inserted into the depressions and outer part of the ridge. The *internal* surface, which is the narrowest of the three, and slightly convex, is nearly parallel with that of the opposite cartilage, and is covered by the laryngeal mucous membrane. The anterior and posterior borders, which limit the internal face, are nearly vertical, whilst the external border, which separates the anterior from the posterior surface, is oblique.

The *base* of each arytenoid cartilage is slightly hollowed, having towards its outer part a smooth concave surface for articulation with the cricoid cartilage. Two of its

angles are remarkably prominent, viz., one *external*, short, and rounded, which projects backwards and outwards, and into which the posterior and the lateral crico-arytenoid muscles are inserted (*muscular process*); the other *anterior*, which is more pointed, and forms a horizontal projection forwards, to which the corresponding true vocal cord is attached (*vocal process*).

The *apex* curves backwards and a little inwards, and terminates in a blunt point, which is surmounted by the corniculum laryngis.

A small cartilaginous nodule (sesamoid cartilage) is sometimes found at the outer side of the arytenoid near the tip, embedded in the perichondrium.

The **cornicula laryngis**, or **cartilages of Santorini**, are two small yellowish cartilaginous nodules of a somewhat conical shape, which are articulated with the summits of the arytenoid cartilages (fig. 169B), and serve, as it were, to prolong them backwards and inwards. They sometimes form part of the arytenoid cartilages.

The **cuneiform cartilages**, or **cartilages of Wrisberg**, are two very small, soft, yellowish, cartilaginous bodies, placed, one on each side, in the fold of the mucous membrane which extends from the summit of the arytenoid cartilage to the epiglottis. They have a conical form, with the base directed upwards. They occasion small elevations of the mucous membrane, a little in advance of the cornicula, with which, however, they are not directly connected.

These cartilages are very frequently absent, especially in the white races of mankind, but according to Gibb are always present in the negro.

The **epiglottis** (fig. 169B, 7) is a median lamella of yellow cartilage, shaped somewhat like an obovate leaf, and covered by mucous membrane. It is placed in front of the superior opening of the larynx, projecting, in the ordinary condition, upwards immediately behind the base of the tongue.

The cartilage of the epiglottis is broad and rounded at its upper free margin, but below it becomes pointed, and is prolonged by means of a long, narrow, elastic band (the *thyro-epiglottic ligament*) to the deep angular depression between the alæ of the thyroid cartilage, to which it is attached behind and below the median notch. Its *lateral* borders, which are convex and turned backwards, are only partly free, the lower parts being enveloped in the aryteno-epiglottic folds of mucous membrane. The *anterior* or *lingual* surface is free only in its upper part, where it is covered by mucous membrane. Lower down, the membrane is reflected from it forwards to the base of the tongue, forming three folds or frænula, the middle and lateral *glosso-epiglottic folds*. This surface is also connected below with the posterior surface of the hyoid bone by a median elastic structure named the *hyo-epiglottic ligament*. The *posterior* or *laryngeal* surface, which is free in the whole of its extent, is concavo-convex from above downwards, but concave from side to side; the convexity projecting backwards into the larynx is named the *tubercle* or *cushion*. The epiglottis is closely covered by mucous membrane, on removing which the yellow cartilaginous lamella is seen to be pierced by numerous little pits and perforations, in which are lodged small glands, which open on the surface of the mucous membrane.

Structure of the cartilages of the larynx.—The epiglottis, the cornicula laryngis, and the cuneiform cartilages are composed of elastic or yellow fibro-cartilage, and have no tendency to ossify. The apices of the arytenoid cartilages are also formed of elastic fibro-cartilage, but the greater part of these, as well as the cricoid and thyroid cartilage, are composed of hyaline cartilage, resembling generally that of the costal cartilages, like which, they are very prone to ossification as life advances.

Peculiarities of the larynx according to age and sex.—In the fœtus the larynx is considerably higher in relation to the vertebral column than in the

adult. Thus, in the sixth month of fœtal life the upper end of the epiglottis is opposite the anterior arch of the atlas and the lower border of the cricoid cartilage, at the level of the middle of the body of the fourth cervical, the whole larynx being thus fully two vertebræ higher than in adult life. Until puberty the larynx gradually descends, by which time it has attained its adult position. This descent of the larynx is, therefore, independent of the special increase in size of the organ occurring at puberty, and appears to be associated with the growth in a vertical direction of the facial part of the skull, which is relatively very small in the fœtus.

Up to the age of puberty the larynx is similar in the male and female, the chief characteristics at that period being the small size and comparative slightness of the organ, and the smooth rounded form of the thyroid cartilage in front. In the female these conditions are permanent, excepting that a slight increase in size takes place. In the male, on the contrary, at the time of puberty, remarkable changes rapidly occur, and the larynx becomes more prominent and more perceptible at the upper part of the neck. Its cartilages become larger, thicker, and stronger, and the alæ of the thyroid cartilage project forwards in front so as to form at their union

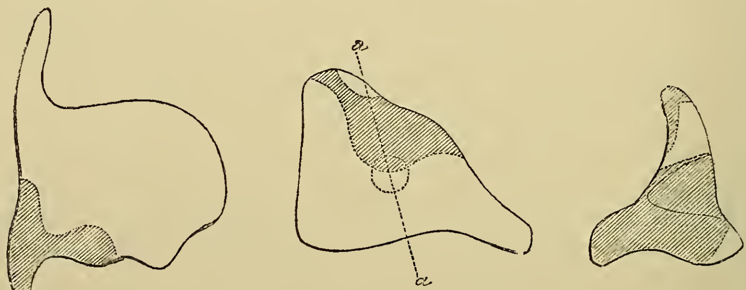


Fig. 170.—Views of thyroid, cricoid, and arytenoid cartilages partially ossified. Portion ossified shaded. (Chievitz.)
The relative proportions of the three cartilages are not kept in this figure.

A, thyroid cartilage, with inferior cornu and adjacent part of ala ossified ; B, cricoid cartilage ossified at upper part ; C, arytenoid almost completely ossified.

with one another the prominent ridge of the *pomum Adami.* At the same time, the median notch on its upper border is considerably deepened. In consequence of these changes in the thyroid cartilage, the distance between its angle in front and the arytenoid cartilages behind becomes greater, and the vocal cords are necessarily lengthened. Hence the dimensions of the glottis, which, at the time of puberty, undergo an increase of about one-third only in the female, are nearly doubled in the male, and the adult male larynx becomes altogether one-third larger than that of the female.

Taguchi found that the average distance from the upper border of the thyroid cartilage to the lower border of the cricoid, measured in the median plane, was in 39 males 4·8 cm. and in 33 females 3·8 cm.

Ossification of the cartilages of the larynx.—At about twenty years of age ossification usually begins in the thyroid and cricoid cartilages, and a few years later in the arytenoids. In the thyroid cartilage ossification takes place first near the inferior cornu, and this is speedily followed by the appearance of a median nucleus in the angle between the alæ ; from the lower cornu the ossification extends along the inferior and posterior borders, and thence spreads through the ala. The cricoid cartilage first becomes ossified at its upper border on each side, near the arytenoid and thyroid articular facets, and the bony masses of the two sides soon become united across the back of the ring ; the lower border remains cartilaginous for some time longer. The arytenoid cartilages become ossified from below upwards. The ossification begins somewhat earlier and proceeds more rapidly in the male than in the female. (J. H. Chievitz, Arch. f. Anat., 1882.)

The cricoid and the arytenoids are the most primitive of the laryngeal cartilages, being found in connection with the air-passages of certain of the amphibia, and also in the reptilia, while the thyroid and the epiglottis, at least in a well-developed condition, are peculiar to mammals. The thyroid cartilage represents the ventral remains of the skeleton of two pairs of visceral arches (4th and 5th), united by a median plate. In the ornithorhynchus these five parts of the thyroid can be recognized as distinct elements, but in the higher mammalia they are more or less blended. In man the two cornua of each ala represent ununited parts of the two arches, while the peculiarities in appearance and structure of the isthmus as compared with the alæ indicate the median portion uniting the arches. According to Dubois the epiglottis represents a chondrification in the submucosa of the glosso-laryngeal fold, the cartilages of Wrisberg being formed in a similar manner in the false cords. Gegenbaur maintains, however, that the epiglottis is an independent element of the skeleton, derived from the sixth pair of visceral arches, and according to Göppert, the cartilages of Wrisberg are formed from the lateral processes of the primitive epiglottis. Small cartilaginous nodules are sometimes found behind or between the arytenoids, which are the rudiments of the pro-cricoids.

LIGAMENTS AND JOINTS OF THE LARYNX.

The larynx is connected with the hyoid bone by a broad membrane, and at the sides of this by two round lateral ligaments. The **thyro-hyoid membrane**, or **middle thyro-hyoid ligament** (fig. 169A, 5), is a broad, fibrous, and somewhat elastic membrane, which passes up from the whole length of the superior border of the thyroid cartilage to the hyoid bone, where it is attached to the posterior and upper margin of the obliquely inclined inferior surface. Owing to this arrangement, the top of the larynx, when drawn upwards, is permitted to slip within the circumference of the hyoid bone, between which and the upper part of the thyroid cartilage there is found a small synovial bursa. The thyro-hyoid membrane is thick where subcutaneous towards the middle line, but at the sides becomes thin and loose, and is covered by the thyro-hyoid muscles. Behind is the epiglottis, with the mucous membrane of the base of the tongue, separated, however, by adipose tissue and mucous glands. This ligament is perforated by the superior laryngeal artery and nerve of each side. The **lateral thyro-hyoid ligaments** (fig. 169A, 6), placed at the posterior limits of the thyro-hyoid membrane, are two rounded yellowish cords, which pass up from the superior cornua of the thyroid cartilage, to the extremities of the great cornua of the hyoid bone. They are distinctly elastic, and there is frequently enclosed in each a small oblong cartilaginous nodule, which has been named *cartilago triticea;* sometimes this nodule is bony.

The thyroid and cricoid cartilages are connected together by a membranous ligament and synovial articulations. The **crico-thyroid membrane** (fig. 169A, 9) is divisible into a median and two lateral portions. The median portion, broad below and narrow above, is a strong, triangular, yellowish ligament, consisting chiefly of elastic tissue, and is attached to the contiguous borders of the two cartilages. Its anterior surface is convex, is partly covered by the crico-thyroid muscles, and is crossed horizontally by a small anastomotic arterial arch, formed by the junction of the crico-thyroid branches of the right and left superior thyroid arteries. The lateral portions are fixed on each side along the inner edge of the upper border of the cricoid, close under the mucous membrane; they become much thinner above, where they are continuous with the inferior thyro-arytenoid ligaments.

The **crico-thyroid articulations,** between the inferior cornua of the thyroid cartilage and the sides of the cricoid, are two small but distinct joints, having each a ligamentous capsule and a synovial membrane. The prominent oval articular surfaces of the cricoid cartilage are directed upwards and outwards, while those of the thyroid cartilage look in the opposite direction. The capsular fibres form a stout band behind the joint. The movement allowed is of a rotatory description, the axis of rotation passing transversely through the two joints. In addition, a slight gliding movement forwards and backwards may occur.

The **superior thyro-arytenoid ligaments** consist of a few slight fibrous fasciculi, contained within the folds of mucous membrane forming the false vocal cords hereafter to be described, and are fixed in front to the angle between the alæ of the thyroid cartilage, somewhat above its middle, and close to the attachment of the epiglottis; behind, they are connected to the inner part of the ridges on the anterior surface of the arytenoid cartilages. They are continuous above with scattered fibrous bundles contained in the aryteno-epiglottic folds.

The **inferior thyro-arytenoid ligaments** are formed of fine closely arranged elastic fibres, which are attached in front to the middle of the angle between the alæ of the thyroid cartilage, and behind to the anterior projection of the base of the arytenoid cartilages. The inner edge of each ligament is free and sharply defined between those attachments, and, covered by the mucous membrane, forms the *true vocal cord* of its own side. In other directions these ligaments are less sharply defined, for in their outer part they spread out both above and below as they pass backwards. Above, the fibres of the ligament lie near the upper surface of the projecting fold of mucous membrane which bounds the rima glottidis, and become gradually merged into the elastic tissue of that membrane. Below, the inferior thyro-arytenoid ligament passes in continuity with the lateral crico-thyroid ligament, so that it may be described as an upward extension of this ligament, and the vocal cord may be stated to be formed by the superior free edge of the crico-thyroid membrane.

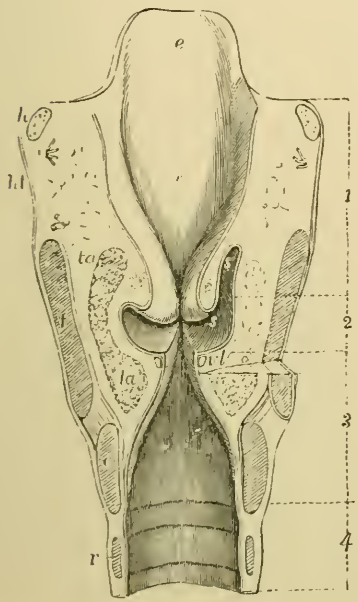
The **crico-arytenoid articulations** are surrounded by a series of thin capsular fibres, which, together with a loose synovial membrane, serve to connect the convex elliptical articular surfaces on the upper border of the cricoid cartilage with the concave articular depressions on the bases of the arytenoid cartilages. The articular surface on the arytenoid cartilage is longer from before back than from side to side ; so that its long axis crosses that of the corresponding surface on the cricoid, and a part of the latter surface is in every position of the arytenoid left uncovered (Henle). The movements allowed are of two kinds, viz. :—1. a lateral gliding movement from within out or *vice versâ*, the arytenoid cartilage being bodily moved away from or towards its fellow ; 2. a rotating movement on a nearly vertical axis, the vocal processes being inclined inwards or outwards (as well as somewhat downwards or upwards). A combined rotating and gliding movement may also occur. The ordinary position of the arytenoid, when the larynx is at rest, is on the outer part of the articular surface on the cricoid. There is a strong **crico-arytenoid ligament**, arising from the cricoid, and inserted into the inner and back part of the base of the arytenoid cartilage.

The summits of the arytenoid cartilages and the cornicula laryngis are sometimes united by a synovial joint, but most frequently by connective tissue forming a sort of syndesmosis.

INTERIOR OF THE LARYNX.

The cavity of the larynx is divided into an upper and a lower compartment by the comparatively narrow aperture of the glottis, or *rima glottidis*, the margins of which, in their anterior two-thirds, are formed by the lower or *true vocal cords ;* and the whole laryngeal cavity, viewed in transverse vertical section (fig. 171) thus presents the appearance of an hour-glass. The upper compartment, often called the *vestibule*, communicates with the pharynx by the *superior aperture* of the larynx, and contains immediately above the rima glottidis the *ventricles* (*s*), with their pouches or *saccules* (*s′*), and the upper or *false vocal cords*. The lower compartment passes inferiorly into the tube of the windpipe without any marked constriction or limitation between them. The whole of the interior of the larynx is lined by mucous membrane.

The **superior aperture** of the larynx, when open, is triangular, wide in front and narrow behind, the lateral margins sloping obliquely downwards and backwards. It is bounded in front by the epiglottis (fig. 173, A, *e*, and fig. 174, *a*), behind by the summits of the arytenoid cartilages (fig. 173, B, *a*) and cornicula (*s*), with the angular border of mucous membrane crossing the median space between them, and on the sides by two folds of mucous membrane, the *aryteno-epiglottic folds*, which, enclosing a few ligamentous and muscular fibres and the cuneiform cartilages



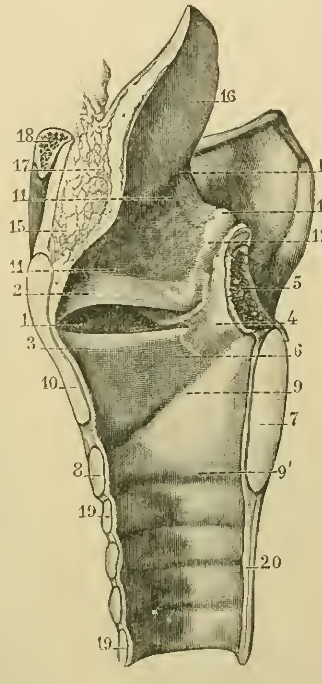


Fig. 171.—Anterior half of a coronal section through the larynx near its middle. (Allen Thomson.)

1, upper division of the laryngeal cavity ; 2, central portion ; 3, lower division, continued into 4, trachea ; *e*, the free part of the epiglottis ; *e'*, its cushion ; *h*, great cornu of the hyoid bone ; *ht*, thyro-hyoid membrane ; *t*, thyroid cartilage ; *c*, cricoid cartilage ; *r*, first ring of the trachea ; *ta*, thyro-arytenoid muscle ; *vl*, inferior thyro-arytenoid ligament in the membrane of the true vocal cord at the rima glottidis ; *s*, the ventricle ; above this, the superior or false cords ; *s'*, the sacculus or pouch opened on the right side by carrying the section further forward.

Fig. 172.—View of the interior of the right half of the larynx. (Sappey.)

1, ventricle ; 2, superior, and 3, inferior vocal cord ; 4, arytenoid cartilage covered by mucous membrane ; 5, arytenoid muscle cut across ; 6, slope of crico-thyroid membrane leading up to inferior vocal cord ; 7, 8, sections of cricoid ; 9, its upper border ; 9', its lower border ; 10, section of thyroid ; 11, upper part of larynx ; 12, 13, glandular prominence in ary.-epiglottic fold ; 14, 16, epiglottis ; 15, fat between it and the thyro-hyoid membrane ; 17, section of epiglottis ; 18, section of hyoid bone ; 19, 20, trachea.

(fig. 173, B, *w*), pass forwards from the tips of the arytenoid cartilages and cornicula to the lateral margins of the epiglottis (fig. 174, 8, 9, 10).

In studying the form of the laryngeal cavity and its apertures, it is well to become acquainted with the appearances which they present on examination during life by means of the laryngoscope, and with the relations of these to the anatomical structure. On thus examining the superior aperture, there are seen on each side two rounded elevations (fig. 173, A, B, *s*, *w*), corresponding respectively to the cornicula and the cuneiform cartilages ;

while in the middle line in front there is a tumescence of the mucous membrane on the lower part of the epiglottis, named the *tubercle* or *cushion of the epiglottis* (*e*).

When the superior aperture is closed during the act of deglutition, it presents, according to Anderson Stuart, a T-shaped fissure. The transverse limb of the T is slightly curved, with the convexity forwards, and is bounded in front by the epiglottis, and behind by the aryteno-epiglottic folds. The vertical limb of the T is represented by a median fissure, extending from the epiglottis in front to the interarytenoid fold behind, and bounded at the sides by the arytenoid cartilages.

On looking down through the superior opening of the larynx, the *glottis* or *rima glottidis* (fig. 173, and fig. 174, *c*) is seen at some distance below, in the form of a long narrow fissure running from before backwards. It is situated on a level with the lower part of the arytenoid cartilages, and is bounded by the *true vocal cords.* Above the glottis another pair of projecting folds is seen, the *superior* or *false*

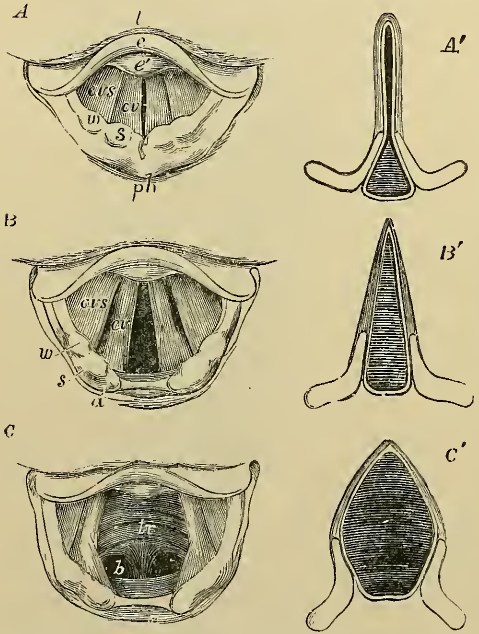


Fig. 173.—Three laryngoscopic views of the superior aperture of the larynx and surrounding parts in different states of the glottis during life. (From Czermak.)

A, the glottis during the emission of a high note in singing. B, in easy or quiet inhalation of air. C, in the state of widest possible dilatation, as in inhaling a very deep breath. The diagrams A′, B′, C′ have been added to Czermak's figures to show in horizontal sections of the glottis the position of the vocal ligaments and arytenoid cartilages in the three several states represented in the other figures. In all the figures, so far as marked, the letters indicate the parts as follows, viz. : *l*, the base of the tongue ; *e*, the upper free part of the epiglottis ; *e′*, the tubercle or cushion of the epiglottis ; *p h*, part of the anterior wall of the pharynx behind the larynx ; in the margin of the aryteno-epiglottidean fold *w*, the swelling of the membrane caused by the cuneiform cartilage ; *s*, that of the corniculum ; *a*, the tip of the arytenoid cartilages ; *c v*, the true vocal cords or lips of the rima glottidis ; *c v s*, the superior or false vocal cords ; between them the ventricle of the larynx ; in C, *t r* is placed on the anterior wall of the receding trachea, and *b* indicates the commencement of the two bronchi beyond the bifurcation, which may be brought into view in this state of extreme dilatation.

vocal cords, which are much less projecting than the inferior. Between the superior and inferior vocal cords the *sinus* or *ventricle* is seen as an elongated depression (fig. 174, *b′*).

The **superior vocal cords** or ventricular bands, also called the *false* vocal cords, because they are not immediately concerned in the production of the voice, are prominent rounded folds of mucous membrane enclosing very numerous glands which form somewhat arched projections, immediately above the corresponding ventricle (fig. 174, *b*). The latter is seen on looking down into the laryngeal cavity, the superior vocal cords (fig. 173, *cvs,*) being further apart than the inferior (*cv*).

Wylie showed (Edin. Med. Journal, 1866) that when the false vocal cords are simply approximated and air is injected into the larynx from below, they prevent the exit of the air, and he held that the closure of the glottis in defæcation and vomiting is mainly effected by the apposition of the false cords. His experiments have been confirmed by Brunton and Cash.

The **inferior or true vocal cords,** the structures by the vibration of which the sounds of the voice are produced, bound the anterior two-thirds of the aperture of the glottis, corresponding with the thyro-arytenoid ligaments (fig. 174, *c*). The mucous membrane covering them is so thin and closely adherent as to show the yellowish colour of the ligaments through it. They are situated at the inner and free edge of a mass of tissue triangular on coronal section (fig. 171). One surface of this mass looks upwards, and forms the floor of the ventricle, another looks downwards and inwards, and bounds the lower division of the laryngeal cavity, while the third is external.

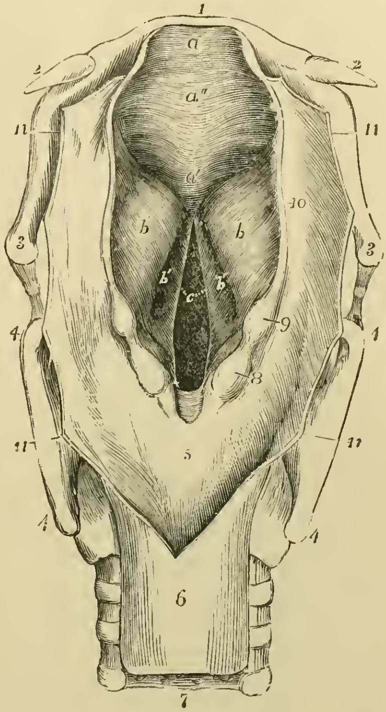
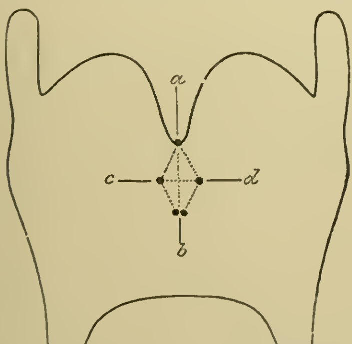


Fig. 174.—Perspective view of the pharyngeal opening into the larynx from above and behind. (Allen Thomson.)

The superior aperture has been much dilated; the glottis is in a moderately dilated condition; the wall of the pharynx is opened from behind and turned to the sides. 1, body of the hyoid bone; 2, small cornua; 3, great cornua; 4, cornua of the thyroid cartilage; 5, membrane of the pharynx covering the posterior surface of the cricoid cartilage; 6, gullet; 7, trachea; 8, projection caused by the cartilage of Santorini; 9, the same belonging to the cartilage of Wrisberg; 10, aryteno-epiglottic fold; 11, cut margin of the wall of the pharynx; *a*, free part of the epiglottis; *a′*, its lower pointed part; *a″*, the cushion; *b*, eminence on each side over the sacculus or pouch of the larynx; *b′*, the ventricles; *c*, the glottis; the lines on each side point to the vocal cords.

A small nodule of elastic cartilage (*cartilage of Luschka*) is found in the anterior and inferior part of the vocal cord (Klein) (fig. 177, *c*).

Taguchi gives the following data for the determination of the position of



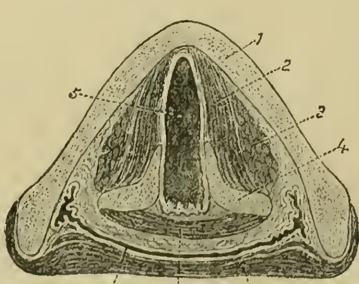


Fig. 175.—Anterior aspect of thyroid cartilage to show points opposite which the true and false vocal cords are attached. (Taguchi.)

a, bottom of thyroid notch; *c* and *d*, opposite attachment of false vocal cords; *b*, opposite attachment of true vocal cords.

Fig. 176.—Horizontal section of the larynx and laryngeal part of pharynx. (J. S.) $\frac{1}{1}$

1, thyroid cartilage; 2, thyro-arytenoid muscle; 3, lateral crico-arytenoid muscle; 4, arytenoid cartilage; 5, rima glottidis; 6, arytenoid muscle; 7, cavity of laryngeal part of pharynx; 8, inferior constrictor of pharynx.

the true and false vocal cords in the undissected body. The true vocal cords are attached to the thyroid cartilage, close to one another, in the male 8·5 mm. and in the female 6·5 below the bottom of the median notch on the upper border of the thyroid cartilage. The false vocal cords are 4 mm. apart at their anterior attachment, and 2·5 mm. higher than the true cords (see fig. 175).

The **rima glottidis,** an elongated aperture, situated, anteriorly, between the inferior or true vocal cords (*pars vocalis*), and, posteriorly, between the bases of the arytenoid cartilages (*pars respiratoria*), forms a long narrow slit, slightly wider in the centre when nearly closed, as in the production of the voice, and opening out to a triangular form in the pars respiratoria (fig. 173, A′). When moderately open, as in easy respiration, its shape is that of a long triangle, the pointed extremity being directed forwards, and the base being behind, between the arytenoid cartilages (fig. 173, B′); in its fully dilated condition it is lozenge-shaped (the posterior sides being formed by the inner sides of the bases of the arytenoid cartilages), while the posterior angle is truncated (C′). The rima glottidis is the narrowest part of the interior of the larynx; in the adult male it measures about 23 mm., or nearly an inch, in an antero-posterior direction, and 6 or 8 mm. across at its widest part, which may be dilated to nearly 12 mm. In the female, and in males before the age of puberty, its dimensions are less, its antero-posterior diameter being about 17 mm., and its transverse diameter about 4 mm. The vocal cords are about 15 mm. long in the adult male and 11 mm. in the female.

The **ventricles** or **sinuses** of the larynx (fig. 171, *s*, and fig. 174, *b′*) are narrower at their orifice than in their interior. The outer surface of each is covered by the upper fibres of the corresponding thyro-arytenoid muscle.

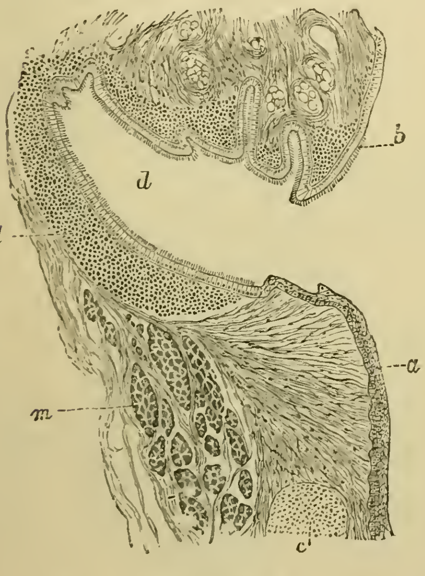
The small recesses named the *laryngeal pouches* (fig. 171, *s′*), lead from the anterior part of the ventricles upwards, for the space of half an inch, between the superior vocal cords inside and the thyroid cartilage outside, reaching as high as the upper border of that cartilage, and nearly to the level of the aryteno-epiglottic folds. The pouch, which is of variable size, is conical in shape, and curved slightly backwards. Its opening into the ventricle is narrow, and is generally marked by two folds of the lining mucous membrane. Numerous small mucous glands, sixty or seventy in number, open into its interior, and it is surrounded by a quantity of fat. Externally to the fat, this little pouch receives a fibrous investment, which is continuous below with the superior vocal cord. Over its laryngeal side and upper end is a thin layer of muscular fibres (*compressor sacculi laryngis, arytæno-epiglottideus inferior*, Hilton) connected above with those found in the aryteno-epiglottic folds. The upper fibres of the thyro-arytenoid muscles pass over the outer side of the pouch, a few being attached to its lower part. The laryngeal pouch is supplied abundantly with nerves, derived from the superior laryngeal.

THE MUCOUS MEMBRANE AND VESSELS OF THE LARYNX.

The laryngeal **mucous membrane** is thin and of a pale colour. In some situations it adheres intimately to the subjacent parts, especially on the epiglottis, and still more in passing over the true vocal cords, on which it is very thin and most closely adherent. About the upper part of the larynx, above the glottis, it is extremely sensitive. In and near the aryteno-epiglottic folds it covers a quantity of loose areolar tissue, which is liable in disease to infiltration, constituting œdema of the glottis. Like the mucous membrane in the rest of the air-passages, that of the larynx is covered in the greater part of its extent with a columnar ciliated epithelium, by the vibratory action of which the mucus is urged upwards. The cilia are found higher up in front than on each side and behind, reaching in the former direction as high as the widest portion of the epiglottis, and in the other

directions only to a line or two above the superior vocal cords; above these points the epithelium loses its cilia, and assumes a stratified squamous form, like that of the pharynx and mouth. Upon the true vocal cords also the epithelium is squamous, although both above and below them it is columnar and ciliated. Patches of stratified squamous epithelium are found also dotted here and there in the ciliated tract above the glottis, especially on the under (posterior) surface of the epiglottis, the inner surface of the arytenoid cartilages, and at the free border of the superior vocal cord. Bodies which are to all appearance similar to the taste-buds which occur in connection with the mucous membrane of the tongue (Vol. III., Pt. 3) are here and there found imbedded in this stratified epithelium (but not over the vocal cords).

The lining membrane of the larynx is provided with numerous *glands,* which secrete an abundant mucus, and the orifices of which may be seen almost everywhere



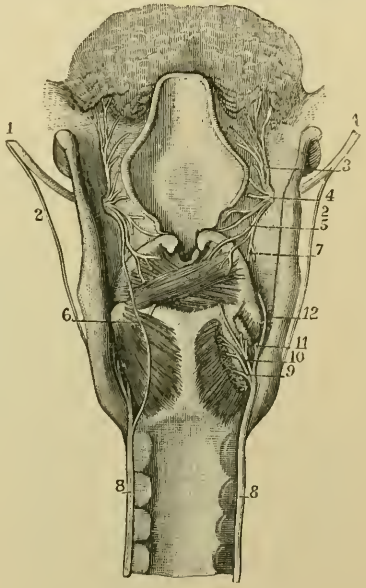


Fig. 177.—Vertical section through the ventricle of the larynx of a child. (Klein.)

a, stratified epithelium over true vocal cord; *b*, ciliated epithelium over false vocal cord; *c*, nodule of elastic cartilage (cartilage of Luschka); *d*, ventricle; *l*, lymphoid tissue; *m*, bundles of thyro-arytenoid muscle, cut across.

Fig. 178.—Posterior view of the nerves of the larynx. (Sappey.)

1, superior laryngeal nerve; 2, its external branch; 3, 4, 5, branches to the mucous membrane of the larynx; 6, filaments uniting the left superior and inferior laryngeal nerves; 7, the same on the right side, cut; 8, 8, inferior laryngeal nerves; 9, branch to the posterior crico-arytenoid muscles; 10, branch to the arytenoid; 11, 12, branches passing to the lateral crico-arytenoid and the thyro-arytenoid muscles.

excepting upon and near the true vocal cords. They abound particularly upon the epiglottis, in the substance of which are found upwards of fifty small compound glands, some of them perforating the cartilage. Between the anterior surface of the epiglottis, the hyoid bone, and the root of the tongue is a mass of yellowish fat, erroneously named the epiglottic gland, in or upon which some small glands may exist. Another collection of glands is placed within the fold of mucous membrane in front of each arytenoid cartilage, from which a series may be traced forwards, along the corresponding superior vocal cord. The glands of the laryngeal pouches have already been noticed.

Vessels and Nerves of the Larynx.—The **arteries** of the larynx are derived from the *superior thyroid*, a branch of the external carotid, and from the *inferior*

thyroid, a branch of the subclavian. The **veins** join the *superior*, *middle*, and *inferior thyroid* veins. The **lymphatics** are divisible into two sets, upper and lower. The upper pierce the thyro-hyoid membrane and join glands near the bifurcation of the common carotid artery ; the lower pass through the crico-thyroid membrane, and end either in one or two small glands often found in front of that membrane, or in some inferior laryngeal glands at the side of the lower part of the larynx. Their mode of distribution resembles that in the trachea. The **nerves** are supplied from the *superior laryngeal* and *inferior* or *recurrent laryngeal* branches of the pneumo-gastric nerves, joined by branches of the *sympathetic*. The superior laryngeal nerves supply the mucous membrane and the crico-thyroid muscles, and also, in part, the arytenoid muscle. The inferior laryngeal nerves supply, in part, the arytenoid muscle, and all the other muscles, excepting the crico-thyroid.

The superior and inferior laryngeal nerves of each side communicate with each other in two places, viz., at the back of the larynx, beneath the pharyngeal mucous membrane, and on the side of the larynx, under the ala of the thyroid cartilage. Numerous ganglion-cells are found on the branches, both on those which enter the

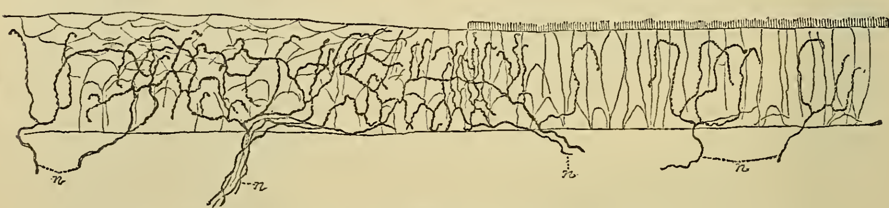


Fig. 179.—Intraepithelial nerve-terminations in the larynx. (G. Retzius.) Silver-chromate preparation.

The section is taken at a place where the ciliated epithelium passes into stratified.

muscles, and also underneath the mucous membrane. End-bulbs are also described in the mucous membrane which covers the posterior or laryngeal surface of the epiglottis (Lindemann). Other nerve-bundles enter the epithelium, within which they end in arborisations of fine fibrils (fig. 179).

The further details of the distribution of the vessels and lymphatics will be found in Vol. II., Pt. 2, and of the nerves in Vol. III., Pt. 2.

MUSCLES OF THE LARYNX.

Besides certain extrinsic muscles elsewhere described—viz., the sterno-hyoid, omo-hyoid, sterno-thyroid, and thyro-hyoid muscles, together with the muscles of the supra-hyoid region, the middle and inferior constrictors of the pharynx, and the stylo-pharyngeus and palato-pharyngeus, all of which act more or less upon the entire larynx—there are other muscles which move the different cartilages upon one another, and modify the size of the apertures and the state of tension of the vocal cords. These intrinsic muscles are the *crico-thyroid*, the *posterior crico-arytenoid*, the *lateral crico-arytenoid*, the *thyro-arytenoid*, the *arytenoid*, and the *aryteno-epiglottic*, together with certain other slender muscular fasciculi. All these muscles, except the arytenoid which crosses the middle line, are in pairs.

The **crico-thyroid muscle** (fig. 180, A, 14) is a short, thick, triangular muscle seen on the front of the larynx. Its attachment below, to the cricoid cartilage, extends from the median line a considerable way backwards, and its fibres passing upwards and outwards, diverging slightly, are fixed above to the inferior border of the thyroid cartilage, and to the anterior border of its lower cornu. The latter portion of the muscle, the fibres of which are nearly horizontal, is usually distinct from the rest. Some of the superficial fibres are almost always continuous with the inferior constrictor of the pharynx. The muscles of the two sides are somewhat

separate from one another in the middle line in front, leaving an interval which is triangular, with the base upwards. The crico-thyroid membrane is here exposed.

Action.—The anterior part of the muscle contracting will approximate the cricoid and thyroid cartilages in front. In this action the thyroid is fixed by the extrinsic muscles, and the anterior part of the cricoid rotating on the axis which unites the articulations between the cricoid and the lower cornua of the thyroid is drawn upwards, and the part behind the crico-thyroid joints is depressed, and with it the arytenoid cartilages, so that the vocal cords are thus put on the stretch. This stretching of the vocal cords is still further assisted by the action of the oblique fibres, which, acting from the cornu of the fixed thyroid, draw the cricoid cartilage backwards. It is found, also, that with electric excitation of this muscle the anterior part of the cricoid is raised towards the thyroid. Paralysis of these muscles is accompanied by inability to produce high tones of the voice.

The **posterior crico-arytenoid muscle** (fig. 180, B, 1), situated behind, arises from the broad depression on the corresponding half of the posterior surface of the cricoid cartilage, and its fibres, converging upwards and outwards, are inserted into

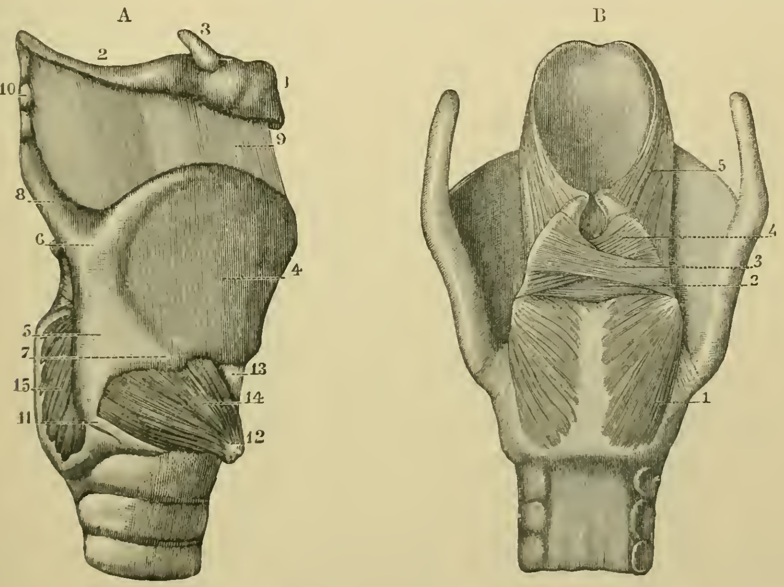


Fig. 180.—Muscles of the larynx. (Sappey.)

A, as shown in a view of the larynx from the right side.

1, hyoid bone ; 2, 3, its cornua ; 4, right ala of thyroid cartilage ; 5, posterior part of the same separated by oblique line from anterior part ; 6, 7, superior and inferior tubercles at ends of oblique line ; 8, upper cornu of thyroid ; 9, thyro-hyoid ligament ; 10, cartilago triticea ; 11, lower cornu of thyroid, articulating with the cricoid ; 12, anterior part of cricoid ; 13, crico-thyroid membrane ; 14, crico-thyroid muscle ; 15, posterior crico-arytenoid muscle, partly hidden by thyroid cartilage.

B, as seen in a view of the larynx from behind.

1, posterior crico-arytenoid ; 2, arytenoid muscle ; 3, 4, oblique fibres passing around the edge of the arytenoid cartilage to join the thyro-arytenoid, and to form the aryteno-epiglottic, 5.

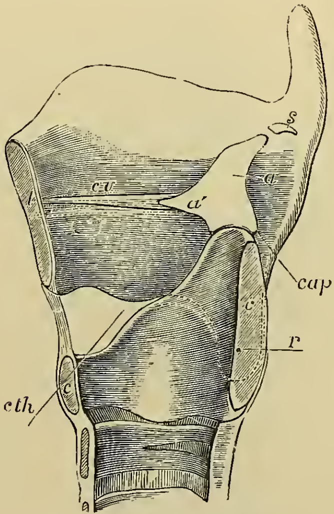
the outer angle of the base of the arytenoid cartilage, behind the attachment of the lateral crico-arytenoid muscle. The upper fibres are short, and almost horizontal ; the middle are the longest and run obliquely ; whilst the lower or external fibres are nearly vertical. Near their insertion the upper fibres are blended with the lower fibres of the arytenoideus.

Action.—The posterior crico-arytenoid muscles draw the outer angles of the arytenoid cartilages backwards and inwards, and thus rotate the anterior or vocal processes outwards, and widen the rima glottidis. Acting with the lateral crico-arytenoid muscles, they approximate the vocal cords (Kanthack). They may also draw the arytenoid cartilages apart. They come into

action during deep inspiration. If paralysed, the lips of the glottis approach the middle line, and come in contact during each inspiration, so that severe dyspnœa may be produced. Expiratory efforts, however, are not impeded, and vocalization is unaffected.

Variety.—In connection with the posterior crico-arytenoid muscle may be mentioned an occasional small slip in contact with its lower border viz., the **kerato-cricoid** muscle of Merkel. It is a short and slender bundle, arising from the cricoid cartilage near its lower border, a little behind the inferior cornu of the thyroid cartilage, and passing obliquely outwards and upwards to be inserted into that process. It usually exists on one side only. Turner found it in seven out of thirty-two bodies. It is not known to be of any physiological significance. (Merkel, Anat. und Phys. des menschl. Stimm-und Spräch-organs, Leipzig, 1857; Turner in Month. Med. Journal, Feb. 1860.)

The **lateral crico-arytenoid muscle** (fig. 182, *cr.ar.lat.*), smaller than the posterior, is in a great measure hidden by the ala of the thyroid cartilage. It lies along the sloping upper border of the cricoid cartilage, from which it arises, its origin extending as far back as the articular surface for the arytenoid. Its



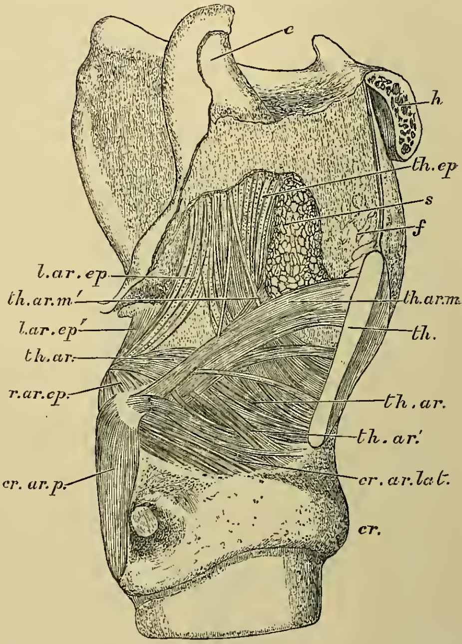


Fig. 181.—Outline of the right half of the cartilages of the larynx as seen from the inside, with the thyro-arytenoid ligament, to illustrate the action of the crico-thyroid muscle. (Allen Thomson.)

t, thyroid cartilage; *c*, cricoid cartilage; *a*, right arytenoid cartilage; *a'*, its vocal process; *s*, corniculum; *c v*, the thyro-arytenoid ligament; the position of the lower cornu of the thyroid cartilage on the outside of the cricoid is indicated by a dotted outline, and *r* indicates the point or axis of rotation of the cricoid cartilage on the cornu of the thyroid; *c t h*, a line in the principal direction of action of the crico-thyroid muscle; *c a p*, the same of the posterior crico-arytenoid muscle.

Fig. 182.—Side view of the larynx after removal of the right ala of the thyroid cartilage. (S. G. Shattock.)

h, body of hyoid bone, cut; *e*, epiglottis; *th*, cut surface of right ala of thyroid cartilage; *cr*, front of cricoid cartilage, the articular facet for the inferior cornu of the thyroid is seen posteriorly; *th.ar*, *th.ar*, fibres of the thyro-arytenoid (outer portion) passing from the thyroid in front to the arytenoid behind; *th.ar'*, others arising from the crico-thyroid membrane; another considerable mass of fibres is seen arising from the same parts, and passing at first obliquely and afterwards nearly vertically upwards as the thyro-epiglottic muscles, *th.ep.*; *th.ar.m*, small thyro-arytenoid; *th.ar.m'*, a small slip of the same muscle passing into the false vocal cord; *cr.ar.lat.* lateral crico-arytenoid; *cr.ar.p*, posterior crico-arytenoid; *r.ar.ep*, right aryteno-epiglottic muscle near its origin; *l.ar.ep*, left aryteno-epiglottic near its insertion; *l.ar.ep'*, portion of the same inserted into the corniculum; *f*, fat; *s*, saccule covered by mucous glands.

fibres pass backwards and upwards, the anterior or upper ones being necessarily the longest, and are attached to the muscular process of the arytenoid cartilage and to the adjacent part of its anterior surface.

This muscle is covered internally by the lateral part of the crico-thyroid membrane, and externally at its anterior part by the upper part of the crico-thyroid muscle. The upper part is in close contact, and, indeed, is always more or less blended with the thyro-arytenoid, and a few of its fibres are continuous round the outer side of the arytenoid cartilage with the arytenoideus muscle.

Action.—These muscles, drawing the muscular processes of the arytenoids forwards and downwards, rotate the vocal processes inwards, and approximate the vocal cords. They thus act antagonistically to the posterior crico-arytenoids.

If both posterior and lateral crico-arytenoids be thrown into action simultaneously, the arytenoids will not undergo rotation, but will be drawn inwards, and the glottis will thus be narrowed.

The **thyro-arytenoid muscle** consists of two portions, one external situated immediately within the ala of the thyroid cartilage, and one internal lying in close contact with the vocal cord. Sometimes these are described as distinct muscles under the names external and internal thyro-arytenoid (Henle), but the separation between them has to be effected by artificial means. The inner portion of the muscle is triangular in section corresponding with the vocal fold which it occupies; the outer is laterally compressed and extends both above and below the inner portion. Each contains both antero-posterior and oblique fibres.

Inner portion.—The antero-posterior fibres of the internal portion arise in the lower half of the angle formed by the alæ of the thyroid cartilage, a few even from a nodule of firmer tissue (cartilage of Luschka) in the anterior part of the vocal cord itself; and, passing backwards in a slight curve with the concavity inwards, are attached behind to the vocal process along its whole length, and to the adjacent part of the outer surface of the arytenoid cartilage. They are joined internally by short fibres, which are attached in front to the vocal cord, and behind to the vocal process of the arytenoid (*portio ary-vocalis* of Ludwig); and externally they are contiguous with the antero-posterior fibres of the external portion. The oblique fibres of the internal portion pass from the sloping portion of the crico-thyroid membrane below the vocal cord proper (in its anterior third), upwards, outwards, and somewhat backwards, passing between the antero-posterior fibres, and over the ventricle of Morgagni, to end in the tissue of the false vocal fold.

Outer portion (fig. 182).—The fibres of the external portion arise in front from the thyroid cartilage, close to the origin of the internal portion, and from the crico-thyroid membrane; from here they in part pass backwards to be inserted into the lateral border and muscular process of the arytenoid cartilage, in part obliquely upwards towards the aryteno-epiglottidean fold, some which are more vertical in direction passing in a thin layer around the ventricle of Morgagni and the sacculus, to end in the false vocal fold. The portion of this muscle which extends towards the epiglottis is often described as a separate muscle under the name of **thyro-epiglottidean** (fig. 182, *th.ep*). It resembles the crico-arytenoideus lateralis in having some of its fibres continuous with those of the arytenoideus.

Action.—The bundles of the thyro-arytenoid muscle, differing as they do in direction and in points of attachment, must differ also in their action, if separately called into play. The antero-posterior fibres will tend to draw forwards the arytenoid, and with it the posterior part of the cricoid cartilage, rotating the latter upwards, and antagonising the action of the crico-thyroid, the effect being to relax the vocal cords. But if the latter be kept stretched and approximated by the action of other muscles, those fibres of the inner portion which are in close contact with the vocal cord may serve to modify its elasticity and consistence, while the fibres which constitute the portio ary-vocalis may serve, as Ludwig has pointed out, to tighten the parts of the cord in front of their attachment, and to slacken the parts behind. The vertical fibres of the muscle which extend from the sloping part of the crico-thyroid membrane across the base of the vocal fold, and over the ventricle into the false vocal cord, must, when they contract, render the free edge more prominent. Finally, the fibres which are inserted into the muscular process and outer surface of the arytenoid will tend to draw

forwards and rotate inwards the arytenoid cartilage, and those which pass up into the aryteno-epiglottidean folds may assist in depressing the epiglottis.

If the thyro-arytenoid muscles are paralysed, the lips of the glottis are no longer parallel, but are curved with the concavity towards one another, and a much stronger blast of air is required for the production of the voice.

Santorini described three thyro-arytenoid muscles, an *inferior*, a *middle*, and a *superior*. The latter is not always present. The inferior thyro-arytenoid muscle of Santorini comprises most of the antero-posterior bundles; the middle thyro-arytenoid, the oblique bundles of the external portion. The fibres of the superior fasciculus, when present, arise nearest to the notch of the thyroid cartilage, and are attached to the upper base of the arytenoid cartilage (fig. 182, *th.ar.m.*). This is named by Sœmmering the *small* thyro-arytenoid, whilst the two other portions of the muscle constitute the *great* thyro-arytenoid of that author.

Arytenoideus muscle.—When the mucous membrane is removed from the back of the arytenoid cartilages, a thick band of transverse fibres is laid bare (fig. 180, B, 2), and on the dorsal surface of this are seen two slender decussating oblique bundles (3, 4).

The transverse and oblique fibres are often described as separate muscles (arytenoid and aryteno-epiglottic), but the two sets of fibres are intimately blended. Most of the anterior or ventral fibres pass straight across between the arytenoid cartilages, and are attached to about the outer half of the concave surface on the back of each. The dorsal fibres can be traced into the lateral walls of the larynx, the uppermost fibres to the cartilages of Santorini, the intermediate fibres run partly independently and partly with the uppermost fibres of the thyro-arytenoidei into the inner and outer walls of the saccules of the larynx, forming the so-called aryteno-epiglottidean muscles, and the lowest fibres blend at the level of the true vocal cords with the thyro-arytenoid and lateral crico-arytenoid muscles.

Action.—The *arytenoid* muscle draws the arytenoid cartilages together, and, from the structure of the crico-arytenoid joints, this approximation, when complete, is necessarily accompanied with depression. If the muscle is paralysed, the intercartilaginous part of the glottis remains patent, although the membranous lips can still be approximated.

The superior aperture of the larynx has been generally supposed to be closed during the act of deglutition by the descent of the upper free end of the epiglottis as a lid over the opening. From observations made by Stuart and McCormack (*The position of the epiglottis in swallowing*, Jour. Anat. and Phys., vol. xxvi.), it has been shown that this is not the case, the epiglottis projecting upwards in close contact with the base of the tongue. According to Stuart (On the mechanism of the closure of the larynx, Proc. Roy. Soc. London, 1892), it is effected by the two arytenoid cartilages being drawn together and also forwards, so that their upper ends are brought in contact with the posterior surface of the epiglottis. These movements of the arytenoid cartilages are produced by the contraction of the arytenoid and thyro-arytenoid muscles.

It is remarked by Henle that the muscles "which lie in the space enclosed by the laminæ of the thyroid cartilage, and above the cricoid, may be regarded in their totality as a kind of sphincter, such as is found in its simplest form embracing the entrance of the larynx in reptiles." In the human larynx there is a marked predominance of adductor over abductor fibres (acting upon the vocal cords).

THE TRACHEA AND BRONCHI.

The trachea is that part of the common air passage of both lungs, which commences above at the larynx and divides below into two smaller tubes, right and left bronchi, one for each lung.

The trachea has a median position in the neck and thorax, and extends from the lower border of the cricoid cartilage of the larynx, on a level with the lower part of the sixth or upper part of the seventh cervical vertebra, into the upper part of the thorax, where it is crossed in front and on the left side by the arch of the aorta and then bifurcates into the two bronchi at about the level of the disc between the fourth and fifth dorsal vertebræ. It usually measures from 4 in. to 4½ in. (10 to 11 cm.) in length, and from ¾ in. to 1 in. (2 to 2½ cm.) in width; but its length varies according to the position of the neck. It is usually stated on the authority of Aeby that the trachea gradually increases in calibre from above downwards, but according

to Braune and Stahel it presents a series of alternate dilatations and contractions. Thus it is smallest at its commencement ; from this point it gradually increases until about midway between its two ends, from here it diminishes to within about 3 cm. of its bifurcation towards which it again enlarges. Its average diameter is greater in the male than in the female. As the trachea passes obliquely downwards and somewhat backwards it gradually recedes from the anterior surface of the neck in its course towards the thorax. If the face be directed forwards the distance from the upper end of the trachea to the top of the sternum is about 2 to 3 in., and this is increased by fully an inch when the head is thrown back. In front and at the sides the trachea is rendered cylindrical, firm, and resistant, by a series of cartilaginous rings ; these, however, are deficient behind, so that the posterior portion is flattened and entirely membranous (fig. 183). Near its bifurcation the trachea is somewhat expanded laterally.

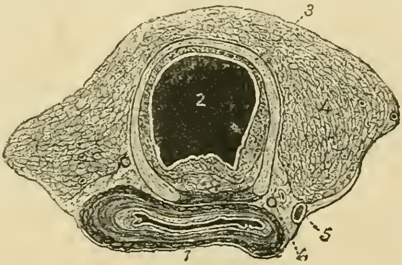


Fig. 183.—Horizontal section of trachea, œsophagus, and thyroid body. (J. S.) $\frac{1}{1}$

1, œsophagus ; 2, cavity of trachea ; 3, cartilaginous ring of trachea ; 4, thyroid body ; 5, inferior thyroid artery ; 6, recurrent laryngeal nerve.

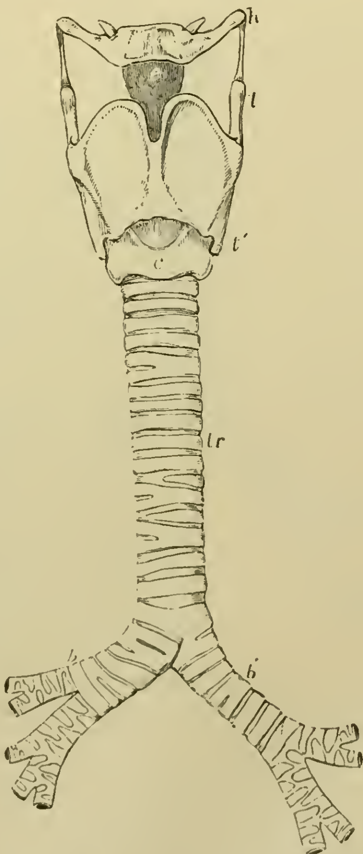


Fig. 184.—Outline showing the general form of the larynx, trachea, and bronchi, as seen from before. (Allen Thomson.) $\frac{1}{3}$

h, the great cornu of the hyoid bone ; *e*, epiglottis ; *t*, superior, and *t'*, inferior cornu of the thyroid cartilage ; *c*, middle of the cricoid cartilage ; *t r*, the trachea, showing sixteen cartilaginous rings ; *b*, the right, and *b'*, the left bronchus. In this and also in the succeeding figure the right bronchus is represented as somewhat more horizontal than is usually described (see p. 164).

Peculiarities according to age.—In the fœtus the trachea is flattened before and behind, its anterior surface being even somewhat depressed : the ends of the cartilages touch ; and the sides of the tube, which now contains only mucus, are applied to one another. The effect of respiration is at first to render the trachea open, but it still remains somewhat flattened in front, and only later becomes convex. In consequence of the high position of the larynx in the infant the cervical part of the trachea is relatively longer at this period of life than in the adult, but this increase in length is somewhat diminished by a higher position of the manubrium sterni. The point of bifurcation of the trachea is generally about a vertebra higher at birth than in the adult. In an infant six months old the trachea will admit a tube 4 mm. in diameter ; at two years one of 5 mm. ; and at six years one of 6 or 7 mm. Ossification of its cartilaginous rings usually commences in the male at about forty years of age, and in the female about sixty (Chievitz).

Relations of the trachea to neighbouring parts.—The windpipe is nearly everywhere invested by a loose areolar tissue, abounding in elastic fibres, and is very moveable on the surrounding parts. Both in the neck and thorax, it rests behind against the gullet, which intervenes between it and the vertebral column, but

towards its lower part projects somewhat to the left side. The recurrent laryngeal nerve ascends to the larynx on each side in the angle between these two tubes.

In the neck the trachea is situated between the common carotid arteries; at its upper end it is embraced by the lateral lobes of the thyroid body, the middle part or isthmus of which lies across it just below the larynx. It is covered in front by the sterno-thyroid and sterno-hyoid muscles, between which, however, there is left an elongated lozenge-shaped interval in the middle line: this interval is covered in by a strong process of the deep cervical fascia, while, more superficially, another layer not so strong crosses between the sterno-mastoid muscles. The inferior

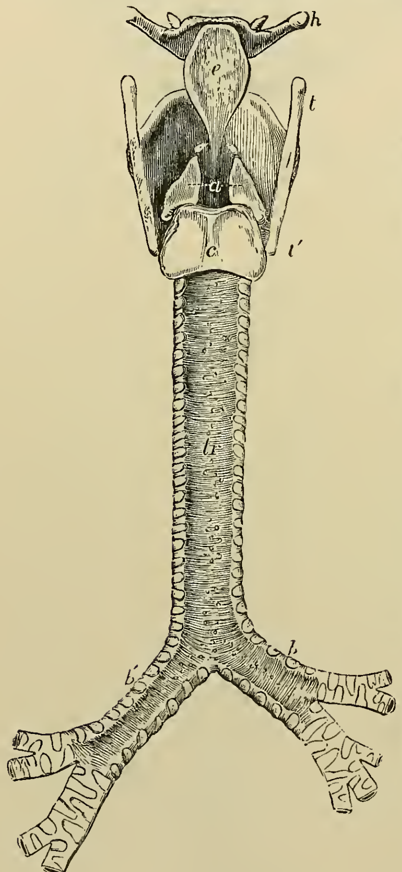


Fig. 185.—Outline showing the general form of the larynx, trachea, and bronchi, as seen from behind. (Allen Thomson.) $\frac{1}{2}$

h, great cornu of the hyoid bone; *t*, superior, and *t′*, inferior cornu of the thyroid cartilage; *e*, the epiglottis; *a*, points to the back of both the arytenoid cartilages, which are surmounted by the cornicula; *c*, the middle ridge on the back of the cricoid cartilage; *t r*, the posterior membranous part of the trachea; *b*, *b′*, right and left bronchi: their relative direction, as shown in this figure, is not that most frequently met with.

thyroid veins and the *arteria thyroidea ima*, when that vessel exists, also lie upon its anterior surface below the isthmus of the thyroid body; while just above the level of the upper edge of the sternum the innominate artery is occasionally found crossing obliquely in front of it.

In the thorax, the trachea is covered by the manubrium sterni, together with the sterno-thyroid and sterno-hyoid muscles and the remains of the thymus gland; behind these, by the left innominate vein, then by the commencement of the innominate artery and left carotid, which pass round to its sides; and lastly by the arch of the aorta and the deep cardiac plexus of nerves. Placed between the two pleuræ, the trachea is contained in the superior mediastinum, and has on its right side the pleura and pneumo-gastric nerve; on the left side are the arch of the aorta, the left carotid and subclavian arteries and the left recurrent laryngeal together with some cardiac nerves.

The **right and left bronchi** (figs. 184, 185, *b*, *b′*) proceed each to the root of the corresponding lung, and then undergo division. Previous to this they exactly resemble the trachea on a smaller scale; being rounded and firm in front and at the sides, where they are provided with imperfect cartilaginous rings, and flattened and membranous behind. The right bronchus is larger than the left, the area of a section at right angles to the long axis of the right bronchus being in the proportion of 100 to 78 for a corresponding section of the left bronchus. It is also more nearly vertical so that on looking down the windpipe towards the bifurcation, the right bronchus appears to be a more direct continuation of the trachea than the left. This is, however, by no means constantly the case. Further it differs from the left in giving off on its outer side about $\frac{1}{2}$ in. to 1 in. from its origin a branch which passes to the upper lobe of the right lung. As this branch comes off *above* the place where the right pulmonary artery crosses the bronchus it is called *eparterial,*

the continuation of the bronchus below this branch being called *hyparterial.* On the left side there is no eparterial branch and the bronchus passes downwards and outwards for about two inches before giving off any branches (see p. 177 and fig. 195).

The *right bronchus* is embraced above by the vena azygos major, which hooks forwards over it to end in the vena cava superior. The right vagus descends behind it. At the root of the lung the eparterial branch is above the pulmonary artery, the hyparterial part is crossed close to its origin by the pulmonary artery and lower down the superior pulmonary vein gets in front of it. The *left bronchus* inclines downwards and outwards beneath the arch of the aorta to reach the root of the left lung where the left pulmonary artery lies first in front of and then above it. It crosses over the front of the œsophagus and the descending aorta. Close to the hilum of the lung the upper left pulmonary vein is in front of it.

The combined sectional area of the two bronchi is about one-fifth greater than that of the trachea.

The distribution of the branches of the bronchi within the lungs will be described in connection with those organs.

STRUCTURE OF THE TRACHEA AND BRONCHI.

Trachea.—The trachea consists of an elastic framework of incomplete cartilaginous rings or hoops united by fibrous tissue, and at one part by plain muscular tissue. It is lined throughout by a mucous membrane, and provided with glands.

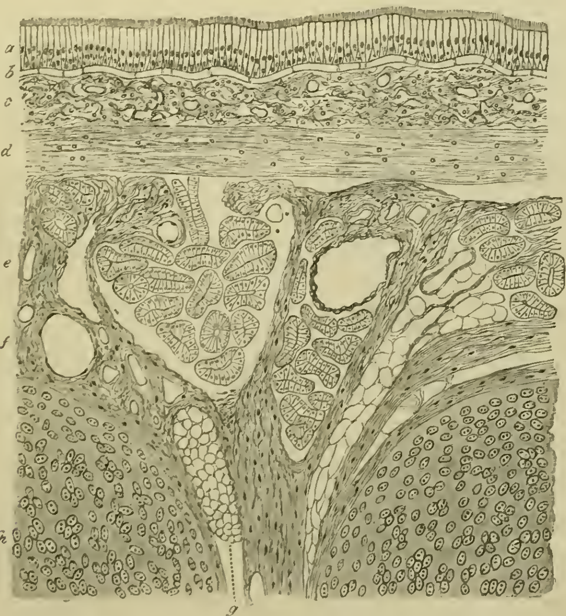


Fig. 186.—Longitudinal section of the human trachea, including portions of two cartilaginous rings. (Klein and Noble Smith.) Moderately magnified.

a, ciliated epithelium ; *b*, basement membrane ; *c*, superficial part of the mucous membrane, containing the sections of numerous capillary blood-vessels and much lymphoid tissue ; *d*, deeper part of the mucous membrane, consisting mainly of elastic fibres ; *e*, submucous areolar tissue, containing the larger blood-vessels, small mucous glands (their ducts and alveoli are seen in section), fat, &c. ; *f*, fibrous tissue investing and uniting the cartilages ; *g*, a small mass of adipose tissue in the fibrous layer ; *h*, cartilage.

The **cartilages** are from sixteen to twenty in number. Each forms a curve of rather more than two-thirds of a circle, resembling the letter C (fig. 183). The depth

from above downwards is three or four millimeters, and the thickness 1 mm. The outer surface of each is flat, but the inner is convex from above downwards, so as to give greater thickness in the middle than at the upper and lower edge. The cartilages are held together by strong fibrous tissue, which is elastic and yielding to a certain extent, and not only occupies the intervals between them, but is prolonged over their outer and inner surfaces, so that they are, as it were, imbedded in the tissue.

The cartilages terminate abruptly behind by rounded ends, but the fibrous tissue is continued across between them, and completes the tube behind: it is here looser in its texture.

The first or highest cartilage, which is connected by the fibrous membrane with the cricoid cartilage of the larynx, is broader than the rest, and often divided at one end. Sometimes it coalesces to a greater or less extent with the cricoid or with the one below. The lowest cartilage, placed at the bifurcation of the trachea, is peculiar in shape; its lower border being prolonged downwards, and at the same time bent backwards so as to form a curved projection between the two bronchi.

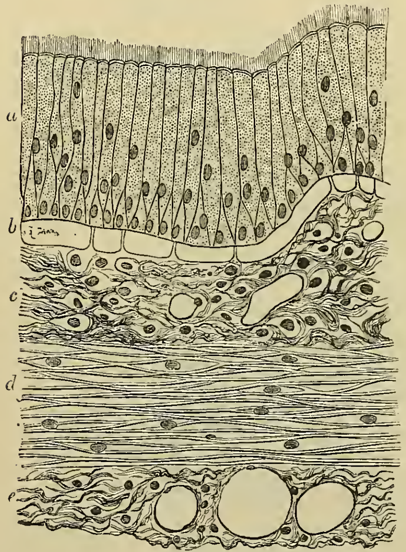


Fig. 187.—A PART OF THE SECTION REPRESENTED IN THE PRECEDING FIGURE MORE HIGHLY MAGNIFIED. (Klein and Noble Smith.)

The letters represent the same parts as in that figure.

The cartilage next above this is slightly widened in the middle line. Sometimes the extremities of two adjacent cartilages are united, and not unfrequently a cartilage is divided at one end into two short branches, the opposite end of that next it being likewise bifurcated so as to maintain the parallelism of the entire series. The use of these cartilaginous hoops is to keep the windpipe open, a condition essential for the free passage of air into the lungs.

Within the fibrous membrane at the posterior flattened part of the trachea, is a continuous pale reddish layer of *unstriped muscular fibres*, which pass across, not only between the ends of the cartilages, but also opposite the intervals; they doubtless serve to narrow the tube by approximating the ends of the cartilages. Those opposite the hoops are attached to the extremities of the latter, and encroach also for a short distance upon their inner surface. Outside the transverse fibres are a few fasciculi having a longitudinal direction.

The submucous tissue consists of loose areolar tissue which serves to connect the mucous membrane with the fibrous layer and the cartilaginous rings. It contains mucous glands and a quantity of adipose tissue is often found in it.

The **mucous membrane** is smooth and of a pale pinkish white colour in health, although when congested or inflamed, it becomes intensely purple or crimson. It contains a considerable amount of lymphoid tissue. Underneath the epithelium is a basement membrane (figs. 186, 187, *b*), well marked in the human trachea, through which nerves and processes from the subjacent connective tissue cells here and there pass into the epithelium. Throughout the mucous membrane a number of fine elastic fibres are found, but in the deeper parts the elastic fibres are very large and numerous (*d*). Along the posterior membranous part, they are more abundant than elsewhere, and are there collected into distinct longitudinal

bundles, which produce visible elevations or flutings of the mucous membrane. These bundles are particularly strong and numerous opposite the bifurcation of the trachea.

The epithelium consists of a layer of long columnar ciliated cells, often very irregular at their fixed end, where they are impressed by smaller cells, between which they penetrate to reach the basement membrane. The cilia serve to drive the mucous secretion upwards towards the larynx. Between these ciliated cells, are found others, also elongated; they are prolonged at one end towards the surface, whilst the other end, which is not unfrequently forked, reaches to the subjacent membrane. These intermediate cells secrete mucus, which is to be seen in them in various stages of formation, and some of them are to be seen converted into goblet-cells by the extrusion of their mucinoid contents (fig. 188). A few lymph corpuscles are also found amongst the epithelial cells, as in other epithelia.

The trachea is provided with numerous small *mucous glands.* The largest are situated at the back part of the tube, either close upon the outer surface of the fibrous layer, or occupying little recesses formed between its meshes. Smaller glands are found between the cartilaginous rings, upon and within the fibrous membrane, and still smaller ones close beneath the mucous membrane. They are

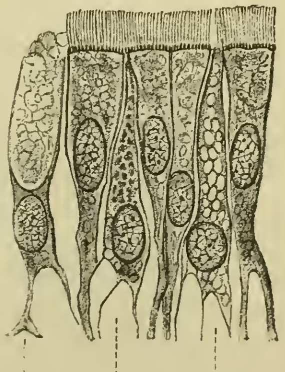


Fig. 188.—Ciliated epithelium cells from the trachea of the rabbit; highly magnified. (E. A. S.)

m^1, m^2, m^3, mucus-secreting cells, lying between the ciliated cells, and seen in various stages of mucin-formation.

racemose glands, and their cavities are lined by a columnar epithelium: the excretory ducts pass through the muscular layer and the mucous membrane, on the surface of which their orifices are perceptible.

Vessels and Nerves.—The **arteries** of the trachea are principally derived from the *inferior thyroid.* The larger branches run for some distance longitudinally, and then join a superficial capillary plexus with polyhedral meshes. The **veins** enter the adjacent plexuses of the *thyroid veins.* A rich plexus of **lymphatics** may readily be injected in the mucous membrane and submucous tissue, but the lymphoid follicles, so common in the alimentary mucous membrane, and also in the walls of the smaller bronchi, are rarely present. When found it is generally surrounding the ducts of the glands as they pass through the mucous membrane. The **nerves** come from the trunk and recurrent branches of the *pneumo-gastric,* and from the *sympathetic* system. There are said to be numerous ganglia upon them, especially outside the muscular layer at the back of the tube.

In the dog, cat, sheep, and rabbit, the upper half of the trachea is said to be supplied chiefly by the *superior laryngeal* nerve, through the anastomosis between the superior and inferior nerves in the larynx (Kandarazi).

Bronchi.—The general structure of the undivided portions of the bronchi corresponds with that of the trachea in every particular. Their cartilaginous rings, which resemble those of the trachea in being imperfect behind, are, however, shorter and narrower. The number of these rings on the right side varies from six to eight, whilst on the left the number is from nine to twelve.

The bronchi are supplied by the bronchial arteries and veins, and the nerves are from the same source as those of the lower part of the trachea.

THE MEDIASTINUM THORACIS.

The greater part of the thorax is occupied by the lungs, each of which is invested by a serous membrane, the *pleura*. The right and left pleural cavities are separated

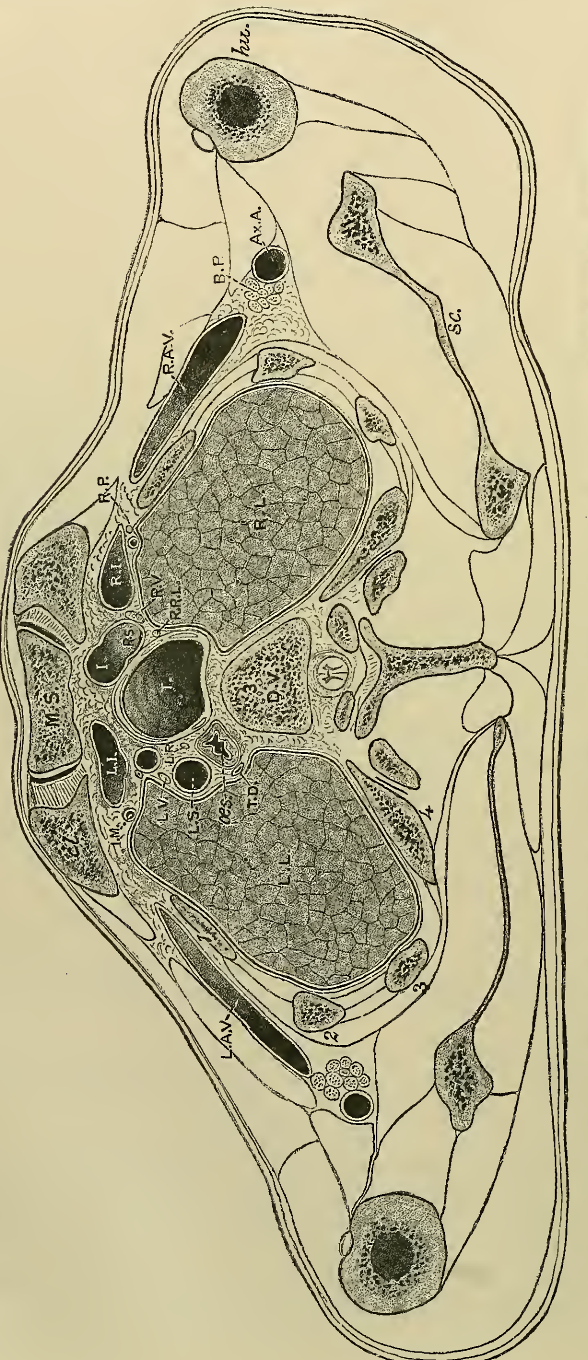


Fig. 189.—Horizontal section of thorax of man, aged 57, at the level of the upper part of the superior mediastinum, seen from above. (J. S.) $\frac{1}{2}$

3 D V., body of third dorsal vertebra; M.S., manubrium sterni; *cl*, clavicle; *sc*, scapula; *hu*, humerus; 1, 2, 3, 4, corresponding ribs; R.L., L.L., right and left lungs; T, trachea; *œs*, œsophagus; T.D., thoracic duct; I, innominate artery; R.S., right subclavian artery; L.S., left subclavian artery, in front of this, not lettered, left common carotid artery; L.M., internal mammary artery; Ax.A., axillary artery; R.I., L.I., right and left innominate veins; R.A.V., L.A.V., right and left axillary veins; R.V., L.V., right and left vagi nerves; R.P., right phrenic nerve, the left phrenic nerve is on outer side of left common carotid artery; L.R., left recurrent laryngeal nerve; R.R.L., right recurrent laryngeal nerve; B.P., brachial plexus.

by a median partition called the *mediastinum.* This consists of a layer of pleura on each side, with the heart, great vessels, pericardium, and other structures interposed. The interval between the right and left pleuræ, which is occupied by the structures referred to, is known as the *mediastinal space.* The whole mediastinum is subdivided into the following parts:—The *middle mediastinum*, which is coextensive with the pericardium; the *anterior mediastinum*, the part in front of the pericardium; the *posterior mediastinum*, the part behind the pericardium; and the *superior mediastinum*, which is situated above the pericardium, and extends upwards as far as the root of the neck.

The **superior mediastinum** may be considered as bounded below by a plane passing from the lower border of the body of the fourth dorsal vertebra behind to the junction of the manubrium with the body of the sternum in front. Its upper limit corresponds with the superior aperture of the thorax. In front are the manubrium and the lower ends of the sterno-hyoid and sterno-thyroid muscles; and behind are the upper four dorsal vertebræ and the lower ends of the longus colli muscles.

It contains the trachea, œsophagus and thoracic duct; the whole of the arch of the aorta, the innominate artery, and the thoracic parts of the left common carotid and subclavian arteries; the innominate veins and upper part of the superior vena cava; the phrenic and pneumo-gastric nerves, the left recurrent, and the cardiac nerves; and the cardiac lymphatic glands and remains of the thymus gland.

The **anterior mediastinum** is narrow in its upper half, the two pleuræ coming nearly or quite into contact behind the second piece of the sternum. Below it is a little broader, the left pleura receding from its fellow, and is bounded in front by the sternum, sometimes also by the fifth and sixth, and a small portion of the seventh left costal cartilages, and by the triangularis sterni muscle; behind it is the pericardium. The enclosed space contains only some areolar tissue, and in its lower part two or three small lymphatic glands (anterior mediastinal glands).

The **middle mediastinum** is the enlarged central portion of the partition, containing in addition to the pericardium with its contents (viz., the heart, the arch of the aorta, the trunk of the pulmonary artery and the lower half of the superior vena cava), the phrenic nerves and accompanying vessels, the arch of the azygos vein, and the roots of the lungs with the bronchial lymphatic glands.

The **posterior mediastinum** is the part between the pericardium, the diaphragm, and the roots of the lungs in front, and the spine behind (from the lower border of the fourth dorsal vertebra downwards). It contains between its pleural layers the descending thoracic aorta; the œsophagus with the pneumo-gastric nerves, the azygos veins, the thoracic duct and the posterior mediastinal lymphatic glands.

THE LUNGS AND PLEURÆ.

The *lungs* occupy by far the larger part of the cavity of the chest, and in health are always in accurate contact with the internal surface of its wall. Each lung is attached at a comparatively small part of its flattened inner or mesial surface by a part named the *root.* In other directions the lung is free, and its surface is closely covered by a serous membrane, which is reflected at the root to the corresponding side of the thorax, and named the (right or left) *pleura.*

THE PLEURÆ.

The **pleuræ** are two serous sacs quite distinct from each other. Each consists of a *visceral* and a *parietal* portion, between which is the pleural cavity containing a very small quantity of fluid, merely sufficient to lubricate the opposing surfaces. The visceral portion (*pleura pulmonalis*) covers the lung and extends into the fissures

between its lobes; and the parietal portion lines the ribs and intercostal spaces (*pleura costalis*), covers the upper convex surface of the diaphragm (*pleura diaphragmatis*), enters into the formation of the mediastinum (*pleura mediastinalis*), and extends upwards into the neck (*pleura cervicalis*).

At the root of each lung the visceral and parietal portions of the corresponding pleura are continuous with one another; and at the lower border of the root is a fold of the serous membrane, the two layers of which are continuous above with those in front of and behind the root of the lung. It extends vertically along the inner surface of the lung down to the diaphragm, to which it is attached by its extremity; this fold is named *ligamentum latum pulmonis*.

Fig. 190.—Horizontal section o thorax of man, aged 57, immediately above the bifurcation of the trachea, seen from above. (J. S.) ½

U.L., upper lobe of right lung; U.P., L.L., upper and lower lobes of left lung; R.B., L.B., origin of right and left bronchi, in this specimen the termination of the trachea was lower than usual; A, arch of aorta; D.A., descending aorta; D, obliterated ductus arteriosus; N, left recurrent laryngeal nerve; L.G., lymphatic glands; other letters as in fig. 189.

Along the mediastinal aspect of each pleura there descends a ligamentous band, an offshoot of the prevertebral fascia, attached above to the bodies of the cervical and first dorsal vertebræ and below to the pericardium and central tendon of the diaphragm. These bands, the "suspensory ligaments of the diaphragm" of Teutleben, embrace the roots of the lungs, and in a measure serve to fix both these and the other parts to which they are attached below.

Relations.—The costal portion of the pleura lines the inner surface of the ribs and intercostal spaces and posteriorly passes over the heads of the ribs and the gangliated cord of the sympathetic on to the sides of the bodies of the dorsal vertebræ, where it becomes continuous with the posterior part of the mediastinal pleura, while in front it is reflected backwards to join the anterior part of the mediastinal pleura. This anterior line of reflection varies at different levels, and also slightly on the two sides. Opposite the manubrium sterni it may be represented by a line passing from the sterno-clavicular articulation downwards and

inwards to meet the pleura of the opposite side at the upper edge of the body of the sternum. From this point the two pleuræ are in close contact down to the level of the upper border of the fifth costal cartilage, where they tend to separate from one another. On the right side the line of reflection continues nearly straight down to the lower end of the body of the sternum, where it begins to turn outwards. On the left side, according to Luschka, it normally diverges from the median line at the upper border of the fifth costal cartilage, so that at the level of the sternal end of the fifth costal cartilage it is 1·5 cm., at the sixth 2 cm., and at the seventh 3·5 cm. external to the left border of the sternum. Not unfrequently, however, the lateral deviation of the left pleura opposite the lower end of the sternum is not so marked

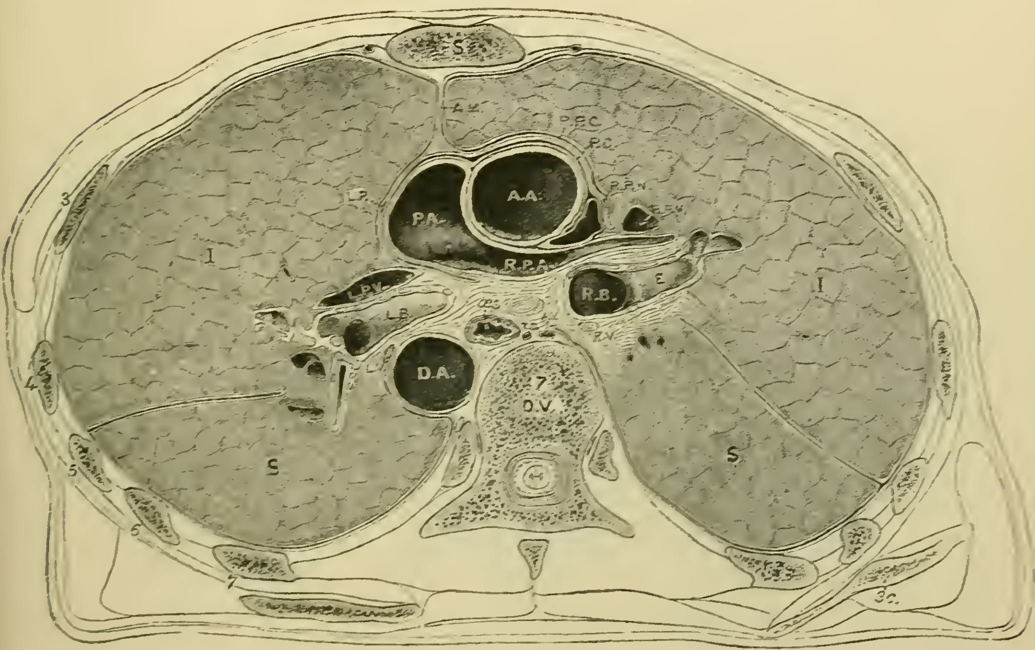


Fig. 191.—Horizontal section of the thorax of a man, aged 57, at the level of the roots of the lungs, seen from above. (J. S.) ½

L., S., superior and inferior lobes of lungs: E. eparterial bronchus; A.M., anterior mediastinum; R.P.C., right pleural cavity; P.C., pericardial cavity: A.A., ascending aorta; P.A., pulmonary artery: R.P.A., its right branch; R.P.V., L.P.V., right and left pulmonary veins: A.V., azygos major vein; other letters as in fig. 189.

as described by Luschka. Thus, Sick, in seventeen out of twenty-three adults, found the reflection of the pleura at the level of the sternal end of the fifth costal cartilage was either behind the sternum or at its left edge. This was also the case in ten out of the twenty-three at the sixth cartilage and in nine of them at the seventh costal cartilage. Brooks' observations also support this view. In four out of seven cases in which the pleura was quite healthy he found the reflection was entirely behind the sternum, while in one it was at the left edge of this bone. He also states that in all the cases the two pleuræ were close to one another as far down as the ensiform cartilage, so that the area of pericardium uncovered by the pleura was reduced to a minimum.

The lower border of the costal pleura is reflected on to the diaphragm opposite a line passing from the lower end of the sternum outwards behind the seventh costal

cartilage nearly as far as its rib ; here it leaves the seventh cartilage, and continuing to pass obliquely downwards and backwards, crosses the eighth, ninth, tenth, and eleventh ribs, and reaches the twelfth rib near its vertebral end. If the twelfth rib be very short the whole of its anterior surface may be covered and the pleura pass as low as the transverse process of the first lumbar vertebra (Pansch). When the rib is well developed it is seldom in contact with the pleura external to its inner half. On the lateral wall of the chest the pleura will generally be found rather lower on the left than on the right side. Luschka estimates that in the midaxillary line the pleura reaches to the lower border of the ninth rib on the right side and to the lower border of the tenth on the left. The inferior limit of the pleura does not

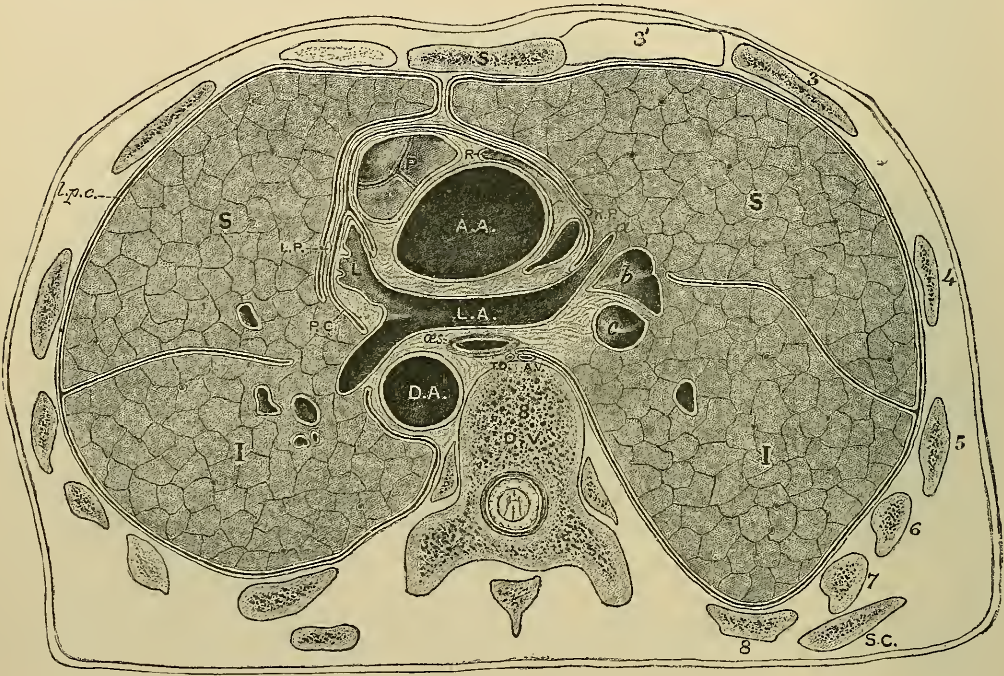


Fig. 192.—Horizontal section of thorax of a man, aged 57, immediately above the pulmonary valves, and the right auricular appendix, seen from above. (J. S.) ½

3′, third costal cartilage ; S.I., superior and inferior lobes of lungs ; P, on right anterior pulmonary valve ; R, tip of right auricular appendix ; L, left auricular appendix ; L.A., left auricle ; *a*, *b*, *c*, branches of right pulmonary artery and vein and of right bronchus ; *l.p.c.*, left pleural cavity ; other letters as in fig. 189.

extend to the attachment of the diaphragm, but leaves a portion of the circumference of this muscle in contact with the costal parietes. Owing to the height of the diaphragm on the right side (corresponding to the greater convexity of the liver) the right pleural sac is shorter than the left ; it is at the same time wider, as the pericardium does not pass so far to the right as to the left of the median plane.

The upper part of the pleura, together with the apex of the corresponding lung, rises dome-like into the root of the neck forming the *pleura cervicalis*. It reaches from one to two inches above the anterior end of the first rib and half an inch to one and a-half inches above the clavicle, but not higher than the neck of the first rib. The subclavian artery, as it arches outwards, lies in a groove on its inner and anterior aspect a little below its highest point. Externally it comes in contact with the scalenus anticus and medius.

A small slip of muscle arising from the transverse process of the last cervical vertebra is described by Sibson as expanding into a dome-like aponeurosis or fascia, which covers or strengthens the pleural cul-de-sac, and is attached to the whole of the inner edge of the first rib.

The mediastinal portions of the two pleural sacs constitute, as already described, the lateral boundaries of the mediastinal space. The layers forming the sides of the anterior mediastinum pass backwards from the sternum to the pericardium in close relation with one another except below, where a triangular interval is sometimes found between them. At the front of the pericardium the two layers separate, each passing round its own side of the pericardium to the front of the root of the corre-

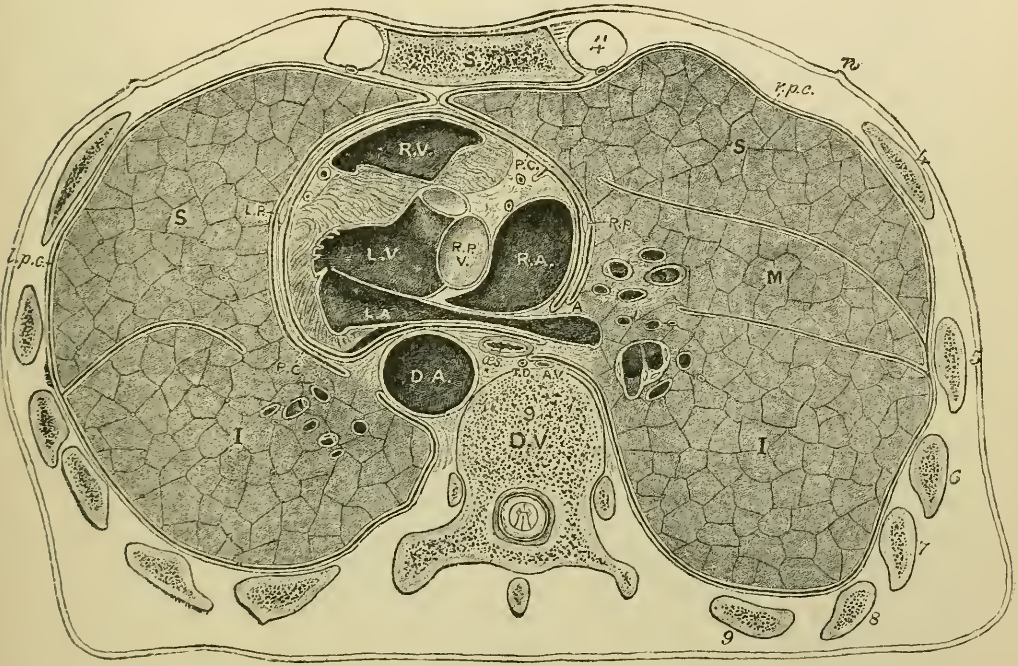


Fig. 193.—Horizontal section of the thorax of a man, aged 57, at the level of the nipples, seen from above. (J.S.) ½

n, nipple; M, middle lobe of right lung; R.A., right auricle; R.V., right ventricle; L.A., left auricle; L.V., left ventricle; R.P.V., right posterior valve of aortic orifice; *r.p.c.*, right pleural cavity; other letters as in fig. 189.

sponding lung, where it becomes continuous with the visceral pleura. This part of the pleura is often termed *pericardial;* it is the lateral limit of the middle mediastinum. The phrenic nerve courses to the diaphragm between it and the pericardium. The pleura which goes from the side of the vertebral column to the back of the root of the lung bounds the posterior mediastinum. On the right side it lies in relation with the vena azygos major, the right vagus, and the œsophagus; on the left side with the descending aorta, and low down with the œsophagus. The two pleuræ are here united by an interpleural ligament passing behind the œsophagus and in front of the aorta. At the level of the superior mediastinum the pleura passes backwards from the anterior to the posterior chest wall without being reflected over the lungs. On the right side it covers the right innominate vein and superior vena cava, the innominate artery and the right phrenic and vagus nerves, and the

trachea ; and on the left the œsophagus and thoracic duct, the left common carotid and subclavian arteries, and the corresponding phrenic and vagus nerves.

In certain situations the surface of the parietal pleura directed towards the pleural cavity is not in contact with the visceral pleura, two portions of parietal pleura being in apposition. The part of the pleural cavity bounded in this way by the parietal pleura is called the supplemental or complemental pleural space. This space varies in its extent according to the condition of the lungs, being diminished in inspiration and increased during expiration ; but in all probability it cannot be completely obliterated even by forcible inspiration. It is found on both sides between the chest wall and the diaphragm, and on the left side between the chest wall and the pericardium, opposite the lower part of the body of the sternum. It is best marked posteriorly, as here the costal and diaphragmatic portions of the pleura are in contact from about the tenth to the twelfth rib.

Structure.—The pleura possesses the usual characters of serous membranes. The costal part is the thicker, and may be easily raised from the ribs and intercostal spaces. It is strengthened here by a layer of subserous areolar tissue of considerable thickness. On the pericardium and diaphragm the pleura is thinner and more firmly adherent ; but it is thinnest and least easily detached upon the surface of the lungs. A difference is also noticeable in the character of the superficial epithelial layers, for while on the *pleura costalis* this consists of the ordinary flattened cells, on the *pleura pulmonalis* the cells are less distinctly flattened and more granular and polyhedral, but they become flattened out when the lung is distended (Klein). Lymphatic vessels are abundant in and beneath the pleura as in other serous membranes, and they communicate in many parts, by means of stomata, with the cavity of the membrane. In the *pleura costalis* the stomata are only found over the intercostal spaces, not over the ribs (Dybkowsky).

Beneath the serous covering there is placed a thin layer of *subserous* areolar tissue mixed with a large number of elastic fibres. It is continuous with the areolar tissue in the interior of the lung, and has been described as a distinct coat under the name of the second or deeper layer of the pleura. In the lungs of many animals, such as the lion, seal, and leopard, this subserous layer forms a very strong membrane, composed principally of elastic tissue ; in others, as the guinea-pig, a network of plain muscular fibres is found, which have a general radiating direction from the apex (Klein). A close plexus of lymphatic vessels is also met with in this sub-pleural tissue : these vessels communicate on the one side by means of stomata with the pleural cavity, and on the other, as will be afterwards noticed, with a network of similar vessels in the inter-alveolar septa of the lungs. A uniform network of capillary veins covers the surface of the lung underneath the pleura. They are supplied with blood from the venules of the superficial pulmonary lobules, but they also receive some blood from the bronchial vessels. They are less closely arranged than the blood-vessels of the pulmonary alveoli, and are thus, as well as by their position, easily distinguishable from them in specimens of injected lung.

THE LUNGS.

Each lung is irregularly pyramidal or conical, with the base downwards (fig. 194). The broad, concave *base* is of a semilunar form, and rests upon the arch of the diaphragm. It is bounded by a thin margin, which is received in the angle between the ribs and the diaphragm, and reaches much lower down behind and at the outer side than in front. The *apex* is blunt, and, as already mentioned, reaches into the root of the neck, above the first rib, where it is separated from the first portion of the subclavian artery by the pleural membrane. The apex is generally marked by a groove where the subclavian artery crosses it. The *outer surface*, which moves upon the thoracic parietes, is smooth, convex, and of great extent, corresponding

with the arches of the ribs and costal cartilages. The *inner surface* is concave, and in part adapted to the convex pericardium. The *posterior* border is rounded, and is received into the deep groove formed by the ribs at the side of the vertebral column ; measured from above downwards, it is the longest part of the lung. The *anterior* border is thin and overlaps the pericardium, forming a sharp edge, which, opposite the middle of the sternum, is separated during inspiration from the corresponding margin of the opposite lung only by the two thin layers of the mediastinal septum. Upon the inner surface, somewhat above the middle of the lung, and considerably nearer to the posterior than the anterior border, is the hilum or fissure, where the bronchi and great vessels enter the lung. These structures form the root of the lung.

The left lung is divided into two lobes by a long and deep fissure, which can be traced on the surface of the lung from the upper and posterior part of the hilum upwards and backwards on the inner surface, and reaches the posterior border at about the level of the fourth rib ; the fissure then passes obliquely downwards and forwards over the outer surface to the lower border, which it joins near its anterior

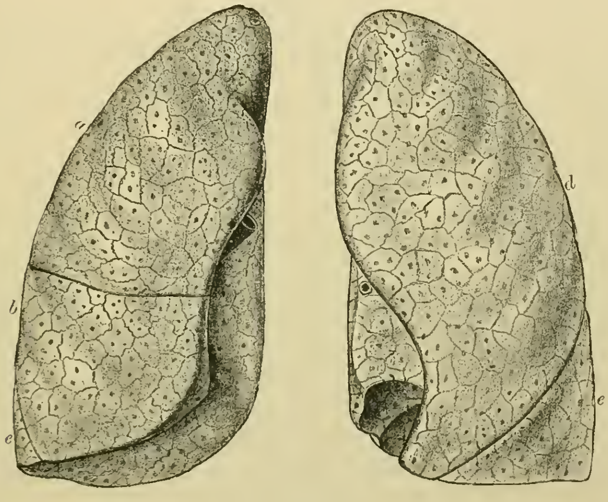


Fig. 194.—View of the lungs from before, drawn from the models of His.

a, *b*, *c*, upper, middle, and lower lobes of the right lung ; *d*, *e*, upper and lower lobes of the left lung.

end. This part of the fissure is somewhat more oblique than the adjacent ribs ; thus, beginning at the fourth rib it gradually leaves it to gain the inner surface of the fifth rib, which it finally crosses to reach the sixth costal cartilage a little below the apex of the heart. From the lower border of the lung the fissure can be seen to pass up the inner surface to the lower part of the hilum. The fissure extends from the surface deeply into the lung, reaching close to the hilum, and practically dividing the lung into two distinct parts. The upper lobe is the smaller. It forms the apex, the whole of the anterior border, and the greater part of the concavity for the heart. To the lower and larger lobe belong the greater part of the thick posterior border and almost the whole of the diaphragmatic surface except a small area in front. The highest part of the lower lobe is found at the posterior border of the lung, where it usually reaches to the fourth rib.

In the right lung there are two fissures dividing it into three lobes, called upper, middle, and lower. One of these fissures closely corresponds in its position and direction with the one on the left side, except that it is rather more vertical, and joins the lower border of the lung farther outwards. It may be regarded as the main

fissure, and separates the lower lobe from both the upper and middle lobes. The additional fissure is seen on the outer surface to pass from the main fissure nearly horizontally inwards and join the anterior border at the level of the fourth costal cartilage. From this border it can be traced on the inner surface backwards to the hilum. Like the main fissure it extends deeply into the lung, and it almost completely cuts off the middle from the upper lobe.

Varieties.—Irregularities in the number and position of the lobes of the lung are not very uncommon. Absence of a lobe owing to its non-development is very rare, but cases of its partial union with the adjacent parts of the lung owing to defective formation of the fissures are often seen. Accessory lobes often result from fissuring of the primary ones. An accessory lobe on the right side situated below the root of the lung, and apparently corresponding to the *lobus impar* of various mammals, has been frequently observed. Several cases have also been recorded of an accessory lobe above the root of the lung, which was constricted at its base by the vena azygos major.

In spite of its comparatively small size, it appears not improbable, from the researches of Aeby, which will be afterwards more fully referred to, that the middle lobe of the right lung is the morphological equivalent of the whole upper lobe of the left lung, and that the upper lobe of the right lung is not represented on the left side.

The left lung has a deep notch in its anterior border, into which the apex of the heart (enclosed in the pericardium) is received. Besides these differences the right lung is shorter than the left, owing to the diaphragm rising higher on the right side to accommodate the liver, whilst the left lung is the narrower, owing to the heart and pericardium encroaching on the left half of the thorax. On the whole, however, as is seen on a comparison of their weights, the right is the larger of the two lungs.

At the summits and posterior borders the extent of the lungs corresponds with that of the pleural sacs which contain them, but in front and below the relation is variable, inasmuch as the anterior margins below the level of the third or fourth costal cartilages pass forwards most completely between the mediastinal and costal pleuræ during inspiration, and retire to a variable degree from between them in expiration ; and in like manner the inferior margins descend, during inspiration, between the costal and diaphragmatic pleuræ; probably at no time do they ever descend completely to the line of reflection between those membranes.

The lower edge of the right lung usually extends to the sixth rib in the mamillary line, to the eighth in the midaxillary, and to the tenth in the post-scapular line. The left lung is often nearly a rib lower than the right.

In consequence of the notch in the lower part of the anterior border of the left lung, an area of the heart, on the left side of the median plane, is uncovered by lung. This area, which is of importance clinically, is often called the area of præcordial dulness, or the area of superficial cardiac dulness. It is irregularly triangular in shape, the three fixed points being, (*a*) one at midsternum opposite the fourth costal cartilages, (*b*) another at the apex beat, (*c*) a third at midsternum at the junction of the body of the sternum with the ensiform cartilage. The line joining the first two of these points is irregularly curved with the convexity directed upwards and outwards. The line joining the second with the third point is slightly curved with the convexity directed downwards and to the right. At the inner part of its lower border cardiac dulness frequently merges in hepatic dulness.

Roots of the Lungs.—The root of each lung is composed of the bronchus or sub-division of the air-tube, and the large blood-vessels, together with nerves, lymphatic vessels, and glands, connected together by areolar tissue, and enclosed by the reflection of the pleura.

The roots of the lungs are situated at the level of the bodies of the fifth, sixth, and seventh, and often also the eighth, dorsal vertebræ. The root of the right lung lies behind the superior vena cava and part of the right auricle, and below the azygos vein, which arches over it to enter the superior cava. That of the left lung passes below the arch of the aorta, and in front of the descending aorta. The phrenic nerve descends in front of the root of each lung, and the pneumogastric nerve

behind, whilst the ligamentum latum pulmonis is continued from the lower border. The bronchus, together with the bronchial arteries and veins, the lymphatics, and lymphatic glands, are placed on a plane posterior to the great blood-vessels, whilst the pulmonary veins are in front of the arteries. The pulmonary plexuses of nerves lie on the anterior and posterior aspect of the root, beneath the pleura, the posterior plexus being the larger of the two.

On the right side the undivided portion of the bronchus is usually altogether above the right pulmonary artery; on the left side the undivided portion of the bronchus, which is considerably longer than on the right side, extends to below the

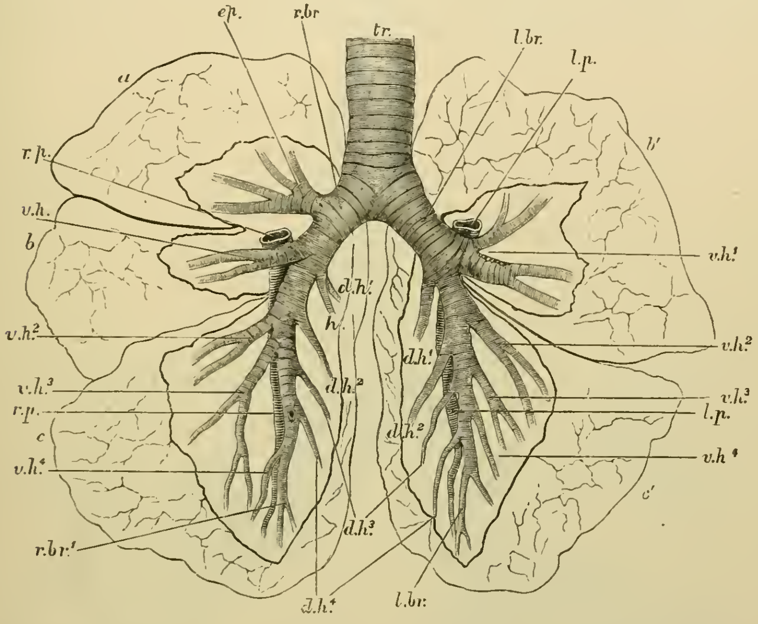


Fig. 195.—Sketch showing the lower end of the trachea, its division into the two bronchial trunks, and the course and chief branches of these within the lungs from before (after Aeby).

a, upper, *b*, middle, *c*, lower, lobe of the right lung; *b'*, upper, *c'*, lower lobe of the left lung: *r.p.*, right pulmonary artery; *l.p.*, left artery; *r.br.*, right bronchial trunk; *l.br.*, left bronchial trunk; *ep.*, on the right side, eparterial branch supplying the upper lobe; *v.h.*[1], first ventral hyparterial bronchus supplying the middle lobe on the right side, the upper lobe on the left; *v.h.*[2], *v.h.*[3], *v.h.*[4], the remaining ventral hyparterial branches distributed in the lower lobe on each side; *d.h.*[1], *d.h.*[2], *d.h.*[3], *d.h.*[4], the four dorsal hyparterial branches distributed on both sides in the posterior and inner part of the lower lobe; *h*, accessory bronchus arising close to the first dorsal hyparterial bronchus on the right side, and representing the one which supplies the azygos lobe in some animals. The main branches of the pulmonary vessels are distributed like the bronchi. Within the lung the arterial trunks run behind the bronchial branches, the venous trunks in front.

level of the left pulmonary artery, which crosses it. On both sides the pulmonary veins are below the corresponding arteries.

Distribution of the bronchi within the lungs.—As already mentioned, the right bronchus gives off a branch near its origin which is distributed in the upper lobe of the lung (fig. 195, *ep*). This branch, which comes off above the place where the right pulmonary artery crosses the bronchus (*eparterial branch*), is not represented on the left side in man, and it is hence inferred by Aeby that the lobe of the lung to which it is distributed is also absent on the left side, and that the upper lobe of the left lung is in reality the homologue of the middle lobe of the right lung. All the other branches of the right bronchus, and all the

branches of the left bronchus, come off below the place where the corresponding pulmonary artery crosses the air-tube (*hyparterial*).

In many animals the bronchi, instead of dividing, as in man they appear to do, into nearly equal branches at the root of the lung, pass down in the form of main trunks towards the extremity of the lower lobe, giving off branches at intervals in two directions, viz., dorsally and ventrally. The character of the ramification of the hyparterial bronchial trunk as it is continued in the lung is therefore bipinnate and not dichotomous. In addition to these two rows of dorsal and ventral branches, accessory branches are occasionally met with coming off from the main trunk in its passage through the lower lobe. These usually arise from the front, and are intermediate in position between the dorsal and ventral series,

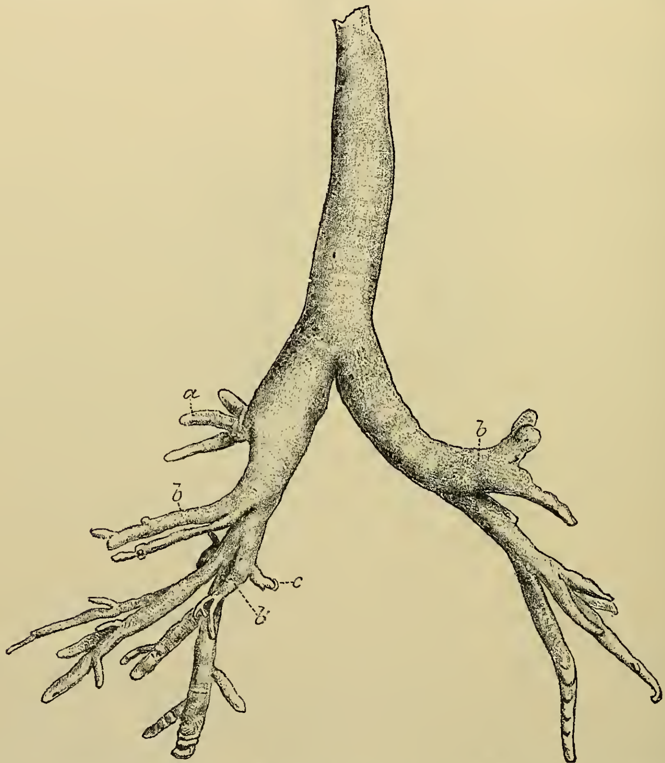


Fig. 196.—Cast of the interior of the trachea and bronchi, with their chief ramifications within the lung. (Aeby.)

This cast shows a type of division frequently met with, the right bronchus being almost in continuation of the line of the trachea.

a, eparterial branch ; *b*, *c*, hyparterial branches (ventral and dorsal).

generally taking origin near one or other of these. Of the accessory bronchi the only one that claims especial notice is that which arises near the second ventral branch of the right bronchial trunk, and which in some animals (monkeys) supplies a special small lobe placed mesially behind the pericardium, and termed by Owen the *azygos lobe*. In some animals well-developed eparterial branches arise from both bronchi, and supply corresponding lobes in the two lungs. This arrangement represents the bilaterally symmetrical type of bronchial distribution. In some (sheep, ox), the eparterial bronchus to the right upper lobe springs directly from the trachea ; and a similar condition has in rare cases been met with in the human subject.

In the human lung the same character of bronchial ramification can be made out (figs. 195, 196, 197). From the continuation of the bronchus four dorsal and as many ventral hyparterial branches are given off in succession in each lung. Of these the ventral or outer are much the larger, and the first ventral branch supplies the middle lobe of the right and the upper lobe of the left lung. But the subordination of the branches to the trunk becomes obscured in consequence of the size of the ventral branches, which are as large in most cases as the trunk itself ; the latter

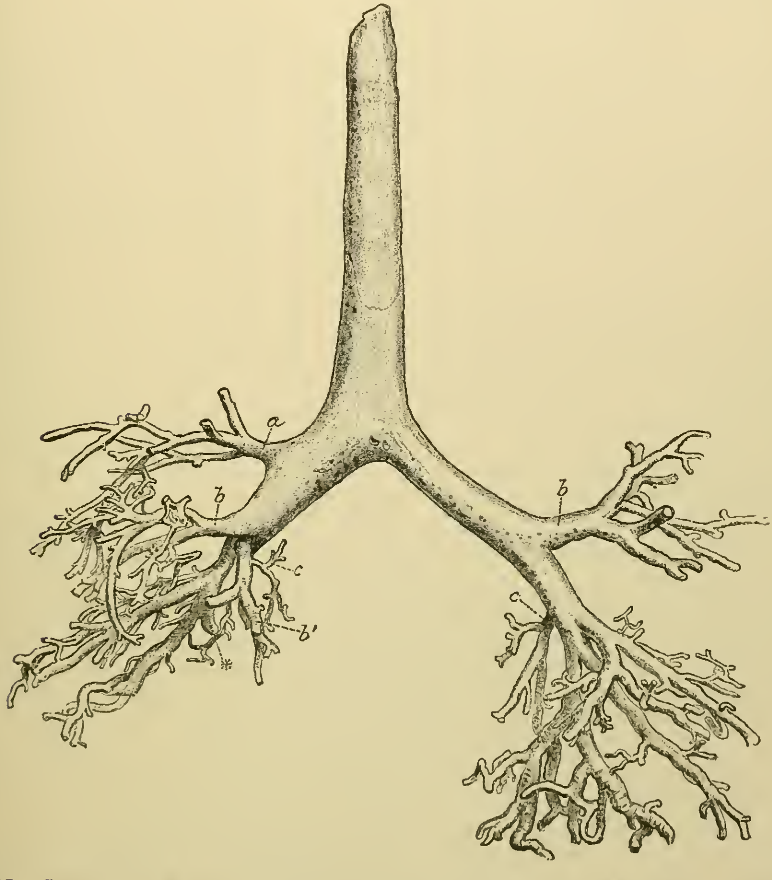


Fig. 197.—Cast of the interior of the trachea and bronchi, with their chief ramifications within the lungs. (Aeby.)

This cast shows a type of division less frequent than the last, the right and left bronchi being at about a right angle with one another.

a, eparterial branch ; *b*, ventral hyparterial branches ; *b'* accessory (azygos) branch ; *c*, dorsal hyparterial branches.

can nevertheless be detected pursuing with but little deviation a course towards the posterior and lower extremity of the inferior lobe.

According to Hasse the larger branches of the bronchi distributed to the upper lobe of the left lung and the upper and middle lobes of the right lung are directed outwards, upwards, and forwards ; while those of the lower lobes of both lungs pass downwards, inwards, and backwards. These directions agree with the movements of the chest walls, which in their upper and anterior parts expand in an upward, forward, and outward direction, while below the descent of the diaphragm increases the chest cavity in a direction downwards and inwards.

On the whole there is a gradual increase in the combined sectional area of the system of air-tubes in proceeding from the lower end of the trachea to the terminations of the bronchial tubes in the lungs ; the increase being only interrupted at one point, namely, immediately below the origin of the first branches which are given off from the bronchial trunks. The combined sectional area is here no greater than the sectional area at the lower end of the trachea, although the combined area of the undivided bronchi is distinctly greater than this. (C. Aeby, Der Bronchialbaum der Säugethiere und des Menschen, Leipzig, 1880.)

Dimensions of the lungs.—The lungs vary much in weight according to the quantity of blood they may happen to contain, as well as from other causes. The weight of both lungs together, as generally stated, ranges from 30 to 48 ounces, the more prevalent weights being found between 36 and 42 ounces (1,300 grammes in the male and 1,023 grammes in the female, according to W. Krause). The proportion borne by the right lung to the left is nearly that of 22 ounces to 20, taking the combined weight of the two at 42 ounces (682 to 618 grammes, taking the combined weight as 1,300). The lungs are not only absolutely heavier in the male than in the female, but appear to be heavier in proportion to the weight of the body.

Their extreme length in the male is 271 mm. for the right and 298 mm. for the left lung ; in the female 216 mm. and 230 mm. respectively. The extreme outer and posterior diameters of the right and left lungs respectively are in the male 203 mm. and 176 mm., and in the female 176 mm. and 162 mm. The transverse diameter at the base is in the male 135 mm. (right) and 129 mm. (left), and in the female 122 mm. (right) and 108 mm. (left). These numbers are also taken from Krause (quoted by Vierordt).

Physical properties.—The substance of the lung is of a light porous spongy texture, and, when healthy, is buoyant in water : but in the fœtus, before respiration has taken place, and also in certain cases of congestion, collapse, or consolidation from disease, the entire lungs, or portions of them, sink in that fluid. The specific gravity of a healthy lung, as found after death, varies from 0·345 to 0·746. When the lung is fully distended its specific gravity is 0·126, whilst that of the pulmonary substance, entirely deprived of air, is 1·056 (Krause). When pressed between the fingers, the lungs impart a crepitant sensation, which is accompanied by a peculiar noise, both effects being caused by the air contained in the tissue. On cutting into the lung, the same crepitation is heard, and there exudes from the cut surface a reddish frothy fluid, which is partly mucus from the air-tubes and air-cells, and partly serum of blood, rendered frothy by the admixed air.

The pulmonary tissue is endowed with great elasticity, in consequence of which the lungs collapse to about one-third of their bulk when the thorax is opened. Owing to this elasticity also, the lungs, if artificially inflated out of the body, contract to their previous volume when the air is again allowed to escape.

In infancy the lungs are of a pale rose-pink colour, which might be compared to blood-froth ; but as life advances they become darker, and are mottled or variegated with spots, patches, and streaks of dark slate-colour, which sometimes increase to such a degree as to render the surface almost uniformly black.

The dark colouring-matter found in these streaks is in the form of granules and collections of granules, frequently not enclosed in cells ; it is deposited in the interstitial areolar tissue mostly near the surface of the lung, and is not found so abundantly in the deeper substance. It exists sometimes in the air-cells, and on the coats of the larger vessels. Its quantity increases with age, and is said to be less abundant in females than in males. In persons who follow the occupation of miners, more especially colliers, the lungs are often intensely charged with black matter. The black substance seems mainly to consist of particles of carbonaceous substance. It is found also in the bronchial glands; indeed, it

appears to be taken up in large measure by the lymphatics. In exceptional cases the adult lungs exhibit only very slight streaks of pigment.

Condition in the fœtus and changes after birth.—In the fœtus the lungs contain no air, and consequently sink in water. They undergo very rapid and remarkable changes after birth, in consequence of the commencement of respiration : these affect their size, position, form, consistence, texture, colour, and weight, and should be carefully studied, as furnishing the only means of distinguishing between a still-born child and one that has respired.

1. *Position, size, and form.*—In a fœtus at the full period, or in a still-born child, the lungs, comparatively small, lie packed at the back of the thorax, and do not entirely cover the sides of the pericardium ; subsequently to respiration they expand, and completely cover the pleural portions of that sac, and are also in contact with almost the whole extent of the thoracic wall, where it is covered with the pleural membrane. At the same time their previously thin sharp margins become more obtuse, and their whole form is less compressed.

2. *Consistence, texture, and colour.*—The introduction of air and of an increased quantity of blood into the fœtal lungs, which ensues immediately upon birth, converts their tissue from a compact, heavy, granular, yellowish-pink, gland-like substance, into a loose, light, rose-pink, spongy structure, which, as already mentioned, floats in water. The changes thus simultaneously produced in their consistence, colour, and texture, occur first at their anterior borders, and proceed backwards through the lungs : they, moreover, appear in the right lung a little sooner than in the left.

3. *Weight.*—The *absolute weight* of the lungs having gradually increased from the earliest period of development to birth, undergoes at that time, from the quantity of blood then poured into them, a very marked addition, amounting to more than one-third of their previous weight : for example, the lungs before birth weigh about one ounce and a half, but after complete expansion by respiration they weigh as much as two and a half ounces. The *relative weight* of the lungs to the body, which at the termination of intra-uterine life is about 1 to 70, becomes, after respiration, on an average about 1 to 35 or 40 ; a proportion which is not materially altered through life. The *specific gravity* is at the same time changed from 1·056 to about ·342.

MINUTE STRUCTURE OF THE LUNGS.

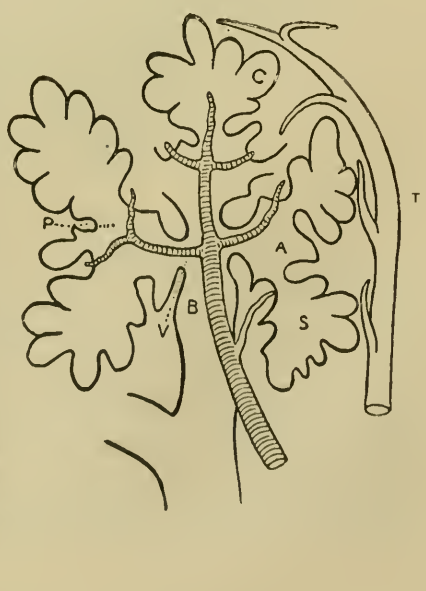


Fig. 198.—Diagram of the ending of a bronchial tube (W. S. Miller).

B, termination of tube in V, vestibule, by means of which it communicates with the atria, A ; S, air-sac, opening out of atrium, and beset with air-cells, C ; P, pulmonary arteriole , T, pulmonary venule.

Termination of the bronchi ; structure of the bronchial tubes. — The principal divisions of the bronchi, as they pass into the lungs, divide into tubes of less calibre, and these again subdivide in succession into smaller and smaller tubes, often distinguished as *bronchia, bronchioles,* or *bronchial tubes*, which, diverging in all directions, never anastomose, but terminate separately. The larger branches pass off at acute angles, but the more remote and smaller ramifications spring

less acutely. After a certain stage of subdivision each bronchial tube, reduced to a small size (about 0·2 mm.), is termed a *lobular* or *respiratory bronchiole* (Kölliker), and its walls become beset here and there with small hemispherical saccules, termed

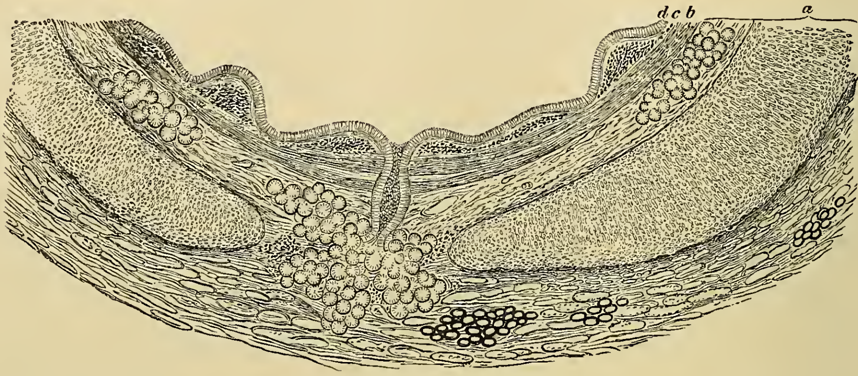


Fig. 199.—Portion of a transverse section of a bronchial tube, human (6 mm. in diameter) (F. E. Schultze). Magnified 30 diameters.

a, cartilage and fibrous layer with mucous glands, and, in the outer part, a little fat; in the middle, the duct of a gland opens on the inner surface of the tube; *b*, annular layer of involuntary muscular fibres; *c*, elastic layer, the elastic fibres in bundles which are seen cut across; *d*, columnar ciliated epithelium.

air-cells, or *alveoli*. Each lobular bronchiole ends in a so-called *vestibule*, out of which open dilatations, which have been termed *atria* by Miller. Each atrium is continued into two or more blind diverticula, which have usually been known as *infundibula*,

Fig. 200.—Section of a small bronchial tube (4 mm. in diameter) from the pig's lung (F. E. Schultze). Magnified 240 diameters.

a, fibrous layer; *b*, muscular layer; *c*, mucous membrane in longitudinal folds, with numerous longitudinally running elastic fibres cut across; *d*, ciliated epithelium; *f*, surrounding alveoli.

but are termed *air-sacs* by Miller: their walls are completely covered with air-cells, which are also found on the walls of the atria (fig. 198).*

Within the lungs the air-tubes are not flattened behind like the bronchi and trachea, but form completely cylindrical tubes. Hence, although they contain the same elements as the larger air-passages, they are reduced gradually to a state of

* Fig. 198 and the accompanying description are taken from W. S. Miller, Journ. of Morph., vol. viii., and have been introduced in reprinting this Part in August, 1898.

greater tenuity, but possess certain peculiarities of structure. Thus, the *cartilages* no longer appear as imperfect rings running only upon the front and lateral surfaces of the air-tube, but are disposed over all sides of the tubes in the form of irregularly shaped plates and incomplete rings of various sizes. These are most developed at the points of division of the bronchia, where they form a sharp concave ridge projecting inwards into the tube. They may be traced, becoming rarer and rarer and more reduced in size, as far as bronchia one millimeter in diameter. The *fibrous* coat extends to the smallest tubes, becoming thinner by degrees, and degenerating into areolar tissue. In it are mucous glands which send their ducts to open on the mucous membrane. These occur most numerously in the larger tubes; in those which measure less than 1 mm. they are rarely if ever found. The *mucous membrane*, which extends throughout the whole system of air-passages, is also thinner than in the trachea and bronchus, but it retains its ciliated columnar epithelium (figs. 199, 200, *d*). The longitudinal bundles of *elastic* fibres (*c*, in the transverse sections) are very distinct in both the large and small bronchia, and may be followed by dissection as far as the tube can be laid open, and by the microscope into the smallest tubes. The *muscular* fibres, which in the trachea and bronchi are confined to the back part of the tube, surround the bronchial tubes with a continuous layer of annular fibres, lying inside the cartilaginous plates (*b*); they are found, however, beyond the place where the cartilages cease to exist, and appear as irregular annular fasciculi even in the smallest tubes.

Pulmonary alveoli.—At the point where the small bronchial tubes lose their cylindrical character, and begin to be beset with air-cells, their structure also gradually undergoes a change. The muscular layer almost disappears, the longitu-

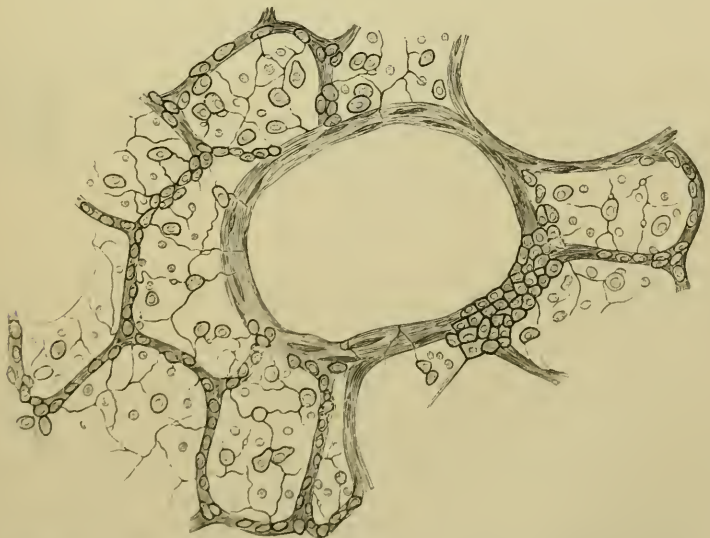


Fig. 201.—Section of part of cat's lung, stained with nitrate of silver (Klein and Noble Smith). Highly magnified.

The small granular and the large flattened cells of the alveoli are shown. In the middle is a section of a lobular bronchial tube, with a patch of the granular pavement epithelium-cells on one side.

dinal elastic bundles are broken up into an interlacement of elastic tissue, which surrounds the mouths of the air-cells and the walls of the infundibula, and the columnar ciliated epithelium gives place to a stratum of non-ciliated cells. The change in the character of the epithelium first occurs in the lobular bronchioles, where patches of small pavement epithelium-cells begin to appear amongst the

ciliated cells, especially in the neighbourhood of the air-cells upon the walls of these tubes. At the end of the lobular bronchiole, near the atrium, all the cells which line the wall of the tube are of the non-ciliated pavement variety. But the air-cells themselves, both those which are scattered over the respiratory bronchioles and those which cover the infundibula, as well as intermediate portions of the infundibula which occur here and there between the air-cells, possess an epithelium of a peculiar character. The cells of this epithelium are of two kinds, viz. :—1, large, thin, very delicate cells, irregular in size and shape, lying over the blood-vessels, but also in many cases extending over the interstices between them ; and, 2, small, flat, polygonal, nucleated cells, which lie singly or in small groups of two or three cells, between the others, and always in the interstices of the capillary network. These are similar to the cells which are found in patches in the lobular bronchioles. If the lung is greatly distended they also become flattened out.

In the fœtus the alveoli are entirely lined with small granular pavement cells, but with the distension which follows upon the first respiratory efforts most of the cells become transformed into the large thin epithelial elements above described.

The walls of the alveoli, which mainly consist of an indistinctly fibrillated connective tissue, with corpuscles scattered here and there, are supported and strengthened by scattered and coiled elastic fibres, especially numerous near their orifices, in addition to which, according to some authorities, there is likewise an intermixture of muscular fibre-cells. A number of leucocytes, mostly granular and eosinophil, are usually to be found free in the air-cells and smaller bronchial tubes : not unfrequently they contain carbonaceous particles. By the migration of these cells into the pulmonary tissue, the carbon particles may be conveyed into the substance of the lung and thence into the lymphatics and bronchial glands.

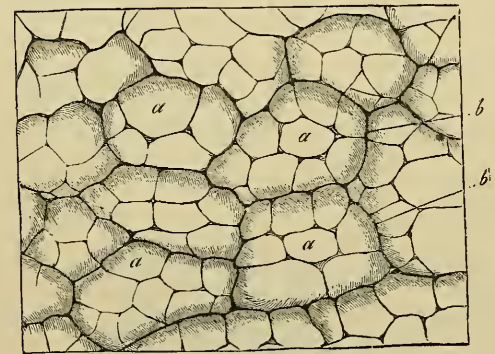


Fig. 202.—Portion of the outer surface of the cow's lung (from Kölliker, after Harting). Magnified 30 diameters.

a, pulmonary vesicles filled artificially with wax ; *b*, the margins of the smallest lobules or infundibula.

The air-cells in the natural state are always filled with air. They are readily seen on the surface and in a section of a lung which has been inflated with air and dried ; also upon portions of fœtal or adult lung injected with mercury or wax (fig. 202, *a*, *a*). In the lungs of some animals, as of the lion, cat, and dog, they are very large, and are distinctly visible on the surface of the organ. In the adult human lung their most common diameter is about 0·25 mm. ($\frac{1}{100}$ inch), but it varies from 0·1 mm. to 0·4 mm. ; they are larger on the surface than in the interior, and largest towards the thin edges of the organ : they are also very large at the apex of the lung. Their dimensions go on increasing from birth to old age, and they are larger in men than in women. In the infant the diameter is usually under 0·12 mm.

The whole lung has a lobulated structure best seen in the fœtus, where the lungs, not yet distended with air, present very much the appearance of compound racemose glands. The infundibula may be regarded as corresponding to the smallest or ultimate lobules of such a gland. They produce the appearance of polygonal areas enclosing groups of six or eight air-cells which are seen at the surface of the lung

(fig. 202). The infundibula are grouped into larger or secondary lobules, and these again into yet larger divisions. The various lobules are united and separated by connective tissue in variable amount, more between the larger and less between the smaller groups. From the mutual compression to which they are subjected the lobules are bounded by flattened sides, and they are compactly fitted to each other and to the larger air-tubes and vessels of the lungs.

Blood-vessels, lymphatics, and nerves of the lungs. Pulmonary vessels.—The branches of the *pulmonary artery* accompany the bronchial tubes, but in their remote ramifications they subdivide more frequently, a branch passing to each atrium, and being distributed to the capillary network of all the infundibula which open out of it (fig. 198, P). The venules commence on the outer border of the air-sacs, and course independently of the arterioles. The main arterial

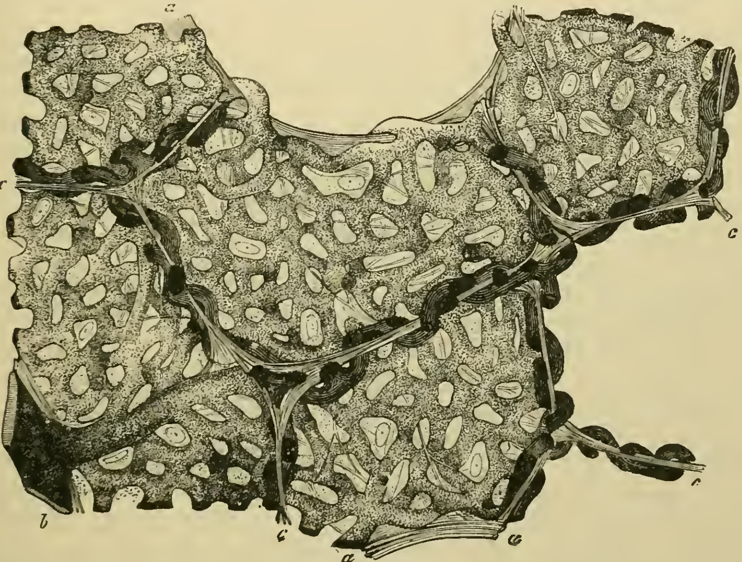


Fig. 203.—Section of injected lung, including several contiguous alveoli (F. E. Schultze). Highly magnified.

a, a, free edges of alveoli ; *c, c,* partitions between neighbouring alveoli, seen in section ; *b,* small arterial branch giving off capillaries to the alveoli. The looping of the vessels to either side of the partitions is well exhibited. Between the capillaries is seen the homogeneous alveolar wall with nuclei of connective tissue corpuscles and elastic fibres.

trunk runs down immediately behind the main bronchial trunk, giving off corresponding branches as it proceeds. They ramify without anastomoses, and the arterioles which pass to the atria send small branches about 0·025 mm. ($\frac{1}{1000}$ inch) in diameter between the air-cells, partially encircling their mouths (fig. 203, *b*). From these vessels the capillary network arises, and covers each alveolus, passing in the interalveolar septa between the adjacent air-cells. As was pointed out by Rainey, the capillary network in these partitions is single in the lungs of man and mammalia, the capillaries winding through the septa from one alveolus to the other, although in the lungs of amphibia and reptiles the capillary network of each alveolus is distinct.

The capillaries are fine, and the network they form so close that the meshes are scarcely wider than the vessels themselves. They are very superficial, being covered only by the thin layer of tesselated epithelium above mentioned, and in the partitions between contiguous alveoli the vessels of the network project on either side in an arched or loop-like manner into the cavities of the alveoli (fig. 203). The mucous membrane of the bronchial tubes, especially near the air-cells, is partly supplied with blood from branches of the pulmonary artery.

The radicles of the *pulmonary veins* arise from the capillary network of the alveoli and from that of the smaller bronchial tubes. Their radicles are collected in the septa between the infundibula, apart from the terminations of the arteries and bronchioles. The branches of these veins which arise from the infundibula near the surface of the lung run alone for a certain distance through the substance of the organ. They finally either join some deeper vein which is passing towards the hilum, or they remain superficial, forming a wide-meshed plexus near the surface of the lung, finally tending towards the hilum to join the larger veins near the root of the lung. The veins from the more deeply lying infundibula form frequent communications, and finally coalesce into large branches, which ultimately accompany the bronchial tubes and arteries, coursing as a rule in front of the bronchial tubes, and thus proceed to the root of the lung. In their course together through the lung the artery is usually found above and behind a bronchial tube, and the vein below and in front.

The pulmonary vessels differ from the systemic in regard to their contents, inasmuch as the arteries convey dark blood, whilst the veins carry red blood. The pulmonary veins, unlike the other veins of the body, are not more capacious than their corresponding arteries ; indeed, according to Winslow, Santorini, Haller, and others, they are somewhat less so. These veins have no valves. The arteries of different secondary lobules are usually independent, the veins freely anastomose.

Bronchial vessels.—The bronchial arteries and veins, which are much smaller than the pulmonary vessels, carry blood for the nutrition of the lung. The *bronchial arteries*, from one to three in number for each lung, arise from the aorta, or from an intercostal artery, and follow the divisions of the air-tubes through the lung. They are ultimately distributed in three ways : (1) many of their branches ramify in the bronchial lymphatic glands, the coats of the large blood-vessels, and in the walls of the bronchial tubes, supplying an outer capillary plexus with transverse meshes to the muscular coat, and an inner plexus with close longitudinal meshes to the mucous membrane, which in the lobular bronchioles is continuous with that supplied by the pulmonary artery ; (2) others form plexuses in the interlobular areolar tissue ; (3) branches pass to the surface of the lung beneath the pleura, and join the network of pulmonary venous capillaries which is found there.

The *bronchial veins* have not quite so extensive a distribution in the lung as the bronchial arteries, since part of the blood carried by the bronchial arteries is returned by the pulmonary veins. The superficial and deep bronchial veins unite at the root of the lung, opening on the right side into the large azygos, and on the left usually into the left upper azygos vein.

According to Zuckerkandl it is not only at the extremities of the bronchial tubes that the blood brought by the bronchial arteries is returned by the pulmonary veins, but in other parts small bronchial veins open into pulmonary branches; and even veins which receive branches from the larger bronchia, from the bronchial glands, and from the posterior surface of the pericardium, empty their contents partly into the great trunks of the pulmonary veins.

A few small branches of the *intercostal arteries* also pass to the pulmonary pleura and surface of the lung through the ligamentum latum pulmonis (Turner).

Lymphatics.—The *alveolar* lymphatics of the lung take origin from lymphatic capillaries in the interalveolar septa, and those near the surface of the lung come into connection with the subpleural lymphatic plexus, previously mentioned (p. 174). They join to form vessels which accompany the branches of the pulmonary artery and vein, running on the walls of those vessels in twos or threes, connected by numerous cross branches, and in some cases almost completely surrounding the blood-vessel.

Other lymphatics, which may be distinguished as *bronchial*, originate in plexuses in the mucous membrane of the bronchial tubes. Hence they pass

through the muscular coat to form another plexus in the fibrous layer, where they are most numerous on the side opposite the accompanying branch of the pulmonary artery. Here they are not unfrequently found to enclose nodules of lymphoid tissue. The branched connective tissue corpuscles and cell-spaces with which the lymphatics are in connection at their origin, send processes upwards to the inner surface of the air tubes and alveoli, between the epithelial cells (like the pseudostomata of the serous membranes). Lymphoid tissue is found, according to Arnold, in various parts, viz., under the pulmonary pleura ; in the perivascular and peribronchial tissue ; in the bronchial wall, and around the alveolar passages.

At the root of the lung the superficial and deep lymphatics unite into a few anastomosing trunks before entering the bronchial lymphatic glands.

Nerves.—The nerves of the lung come from the *anterior and posterior pulmonary plexuses*, which are formed chiefly by branches from the pneumo-gastric nerves, joined by others from the sympathetic system. The fine nervous cords enter at the root of the lung, and follow the air-tubes. According to Remak, whose account has been confirmed and added to by the more recent observations of Stirling and others, they include both white fibres, derived in all probability from the vagus, and grey filaments proceeding from the sympathetic, and have ganglion-cells, both singly and in groups, upon them in their course. In the lower vertebrates (frog, newt) the nerves are chiefly distributed to a layer of plain muscular tissue, which is everywhere found taking part in the composition of the relatively simple pulmonary wall (Stirling). Berkeley has described the nerve-endings in mammals as forming a plexus of fine fibrils with interspersed stellate cells such as have been noticed in many glands and mucous membranes. The ultimate ending appears to be in open arborisations upon and between the alveoli.

RECENT LITERATURE OF THE RESPIRATORY ORGANS.

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THE URINARY ORGANS.

By E. A. SCHÄFER and J. SYMINGTON.

The urinary organs consist of the *kidneys*, the glands by which the urine is secreted, and the *ureters, bladders* and *urethra*, serving for its reception and evacuation.

THE KIDNEYS.

The **kidneys,** two in number, are deeply situated in the loins, lying one on each side of the vertebral column, at the back part of the abdominal cavity, and behind

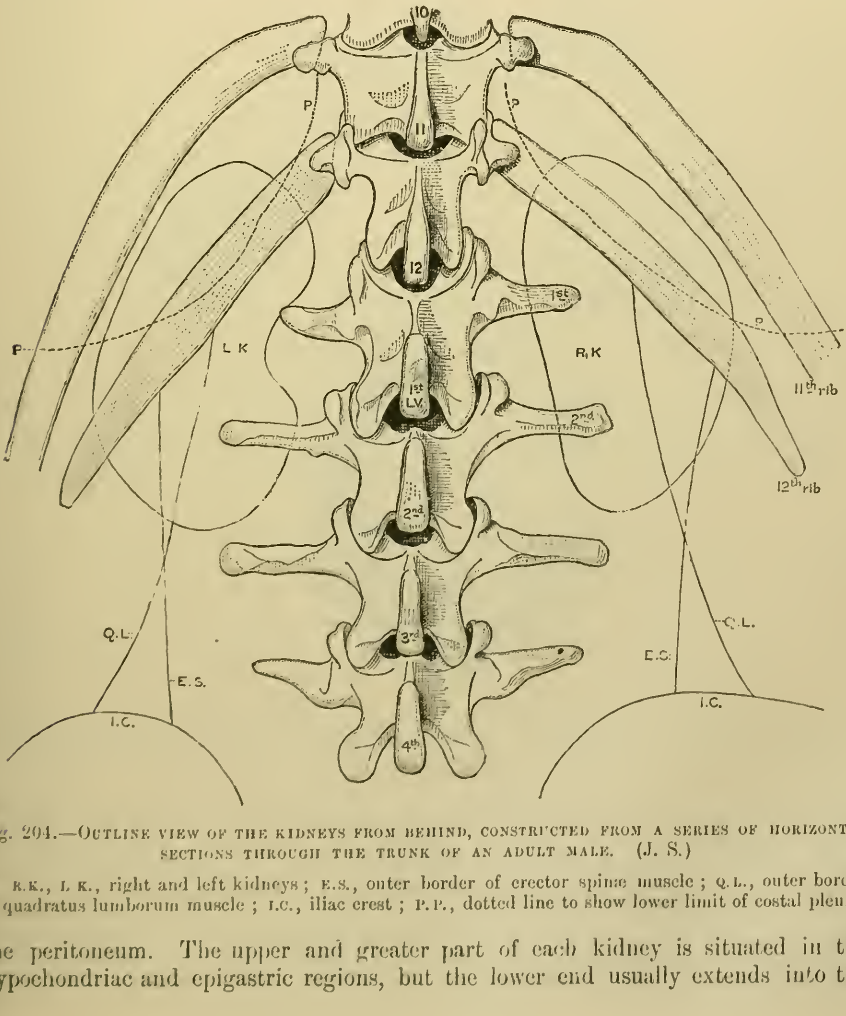


Fig. 204.—Outline view of the kidneys from behind, constructed from a series of horizontal sections through the trunk of an adult male. (J. S.)

R.K., L.K., right and left kidneys; E.S., outer border of erector spinæ muscle; Q.L., outer border of quadratus lumborum muscle; I.C., iliac crest; P.P., dotted line to show lower limit of costal pleura.

the peritoneum. The upper and greater part of each kidney is situated in the hypochondriac and epigastric regions, but the lower end usually extends into the

adjacent portions of the lumbar and umbilical regions. They are on a level with the last dorsal and the upper two or three lumbar vertebræ (fig. 204), the right kidney being usually a little lower than the left, probably in consequence of the vicinity of the great right lobe of the liver. They are maintained in this position by their vessels, by a quantity of surrounding loose areolar tissue, which usually

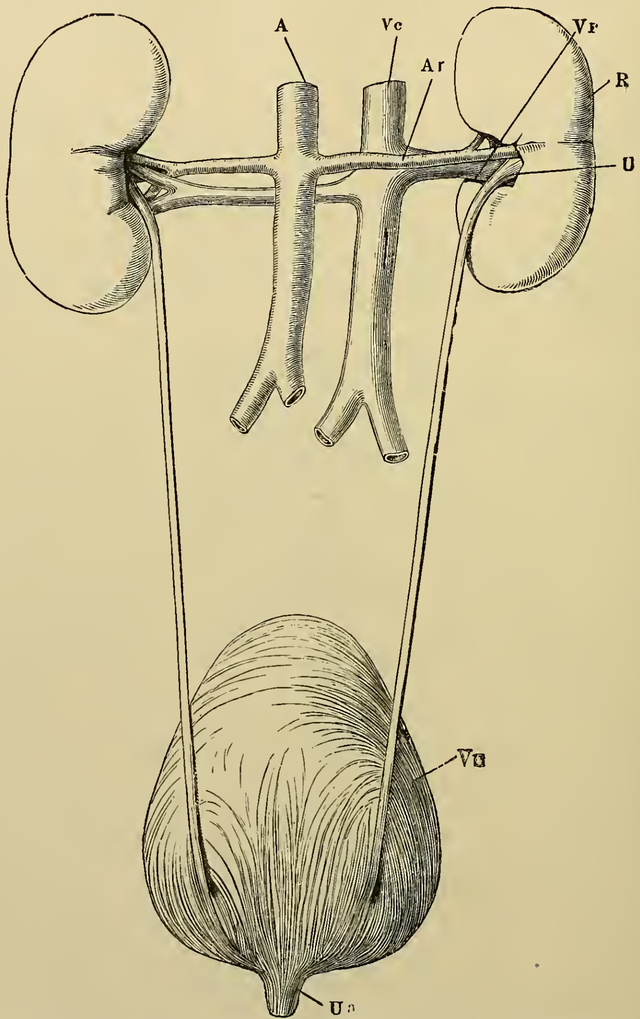


Fig. 205.—The urinary organs of the female from behind (Henle).

R, right kidney ; U, commencement of the ureter ; A, aorta, Ar, right renal artery, Vc, vena cava ; Vr, right renal vein ; Vu, urinary bladder ; Ua, commencement of urethra. $\frac{1}{3}$

contains much fat (*capsula adiposa*), and by the tonicity of the muscles of the abdominal wall.

The kidneys measure about four inches (100 mm.) in length, two-and-a-half inches (60 mm.) in breadth, and one-and-a-quarter or one-and-a-half in thickness. The left is usually longer and narrower and a little heavier than the right. The weight of the kidney is usually stated to be about four-and-a-half ounces in the male, and somewhat less in the female. Vierordt gives 277 g. as the weight of the two kidneys together in the male. The specific gravity is about 1·050.

Form and relations.—The surface of the kidney is smooth and of a deep red colour. It is bean-shaped, and possesses two surfaces, an *anterior* looking forwards and outwards, and a *posterior* backwards and inwards; two borders, an *outer*, which is convex, and an *inner*, concave; and two somewhat enlarged convex extremities, *upper* and *lower*. Its long axis is directed from above downwards and slightly outwards. The posterior surfaces of the two kidneys lie against the abdominal wall and are nearly identical in their relations, but the connections of their anterior or visceral surfaces differ on the two sides. The *posterior surface*, embedded in areolar and adipose tissue and uncovered by peritoneum, rests upon the last rib and sometimes, more particularly on the left side, also upon the eleventh rib; the diaphragm; the anterior layer of the lumbar aponeurosis covering the quadratus lumborum, and the psoas, these two muscles intervening between the kidney and the transverse processes of the first and second lumbar vertebræ. The pleura descends behind the upper part of the kidney, separated, however, from it by the diaphragm. Below the twelfth rib the last dorsal, ilio-inguinal and

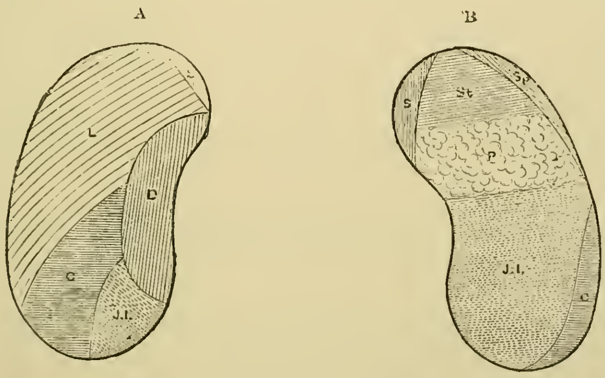


Fig. 206.—DIAGRAM TO ILLUSTRATE THE RELATIONS OF THE KIDNEYS, AS SEEN FROM BEFORE. (J. S.)

A, *right kidney;* S, area for right suprarenal capsule, non-peritoneal; L, area for liver, peritoneal; D, area for second part of duodenum, non-peritoneal; C, area for ascending colon and hepatic flexure of colon, non-peritoneal; J.I., area for convolutions of jejuno-ileum, peritoneal. B, *left kidney;* S, area for left suprarenal capsule, non-peritoneal; St, area for stomach, peritoneal; Sp, area for spleen, peritoneal; C, area for splenic flexure and descending colon, non-peritoneal; J.I., area for convolutions of jejuno-ileum, peritoneal; P, area for pancreas, non-peritoneal.

ilio-hypogastric nerves pass outwards behind it. The *anterior surface* of the right kidney is covered on its upper and outer part by peritoneum which intervenes between it and the large renal impression on the liver. Near its inner border the second part of the duodenum descends in contact with it, while more externally it is crossed by the commencement of the transverse colon; both those portions of the intestine are destitute of peritoneum posteriorly. The lower end of the right kidney is again covered by peritoneum. The *anterior surface* of the left kidney is crossed transversely, just above the level of the hilum, by the pancreas and the splenic vessels. Above this there is usually a small area covered by the stomach, the lesser sac of the peritoneum intervening. Below the pancreas it is separated from some coils of the small intestine by the peritoneum. The *upper end* of the right kidney is capped by the right suprarenal capsule and the liver, and that of the left kidney by its capsule and the spleen. The *lower ends* of the kidneys are generally smaller than the upper. They reach on an average to within about 2 inches of the iliac crest. The *outer border* of the right kidney is covered in about its upper two-thirds by the liver, and the left kidney in its upper half or more by the spleen. The ascending colon on the right side and the splenic flexure and descending

colon on the left are found at the lower and outer parts of the right and left kidneys respectively. The *inner border* presents about its middle third a vertical fissure termed the *hilum*, which is bounded by anterior and posterior lips. The direction of the hilum varies considerably in different subjects and even on the two sides in the same individual, but as a rule it looks more forwards than towards the middle line, and not unfrequently the posterior lip reaches as far forwards as the anterior one.

D. J. Cunningham has shown that the kidneys when hardened *in situ* present facets corresponding to the viscera with which they are in contact, and the posterior surfaces also have slight depressions opposite the last rib, and the transverse processes of the upper two lumbar vertebræ.

Varieties.—The kidneys sometimes vary from their normal form, being either longer and narrower, or shorter and more rounded. The characteristic fœtal lobulation may persist in the adult. Occasionally one kidney is very small, while the other is proportionately enlarged. Upward displacement is very uncommon, but they are often found lower than normal, lying more or less entirely in the iliac fossa, or with their lower ends projecting into the true pelvis. Numerous cases are recorded of absence of one kidney, most frequently the left. The single kidney is usually enlarged, but not invariably. The occurrence of an additional kidney is extremely rare, the supernumerary organ is placed either in front or on one side of the vertebral column or in the pelvic cavity.

Instances are now and then met with in which the two kidneys are joined by their lower ends across the front of the great blood-vessels and vertebral column. The conjunct organ has usually the form of a horse-shoe. Sometimes two united kidneys are situated on one or other side of the vertebral column in the lumbar region, or, but much more rarely, in the cavity of the pelvis.

The kidney may be *movable* owing to the laxity of its areolar and adipose capsule, or in rare cases *floating*, when it has a more or less distinct mesonephron, and the peritoneum moves with the organ. These conditions occur much more frequently in connection with the right than the left kidney.

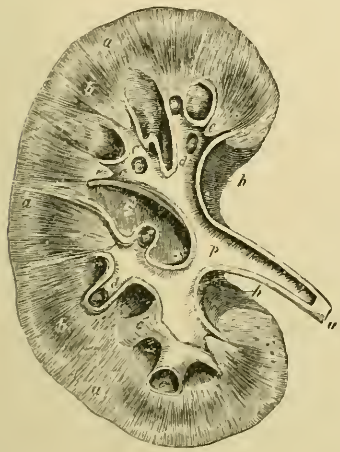
Structure.—The kidney is surrounded by a proper fibrous coat, which forms a thin, smooth, but firm investment, closely covering the organ. It consists of dense areolar tissue, with numerous fine elastic fibres, and can easily be detached from the substance of the gland, to which it adheres by minute processes of connective tissue and vessels. Underneath the capsule in the human kidney is an incomplete layer of plain muscular fibres.

On splitting open the kidney by a longitudinal section, from its outer to its inner border, the fissure named the hilum (fig. 207, *h*, *h*) is found to extend some distance into the interior of the organ, forming a cavity called the *sinus* of the kidney (*s*). This is enclosed on all sides except at the hilum by the solid substance of the organ ; and is lined by an inward prolongation of the fibrous coat. The solid part consists of *cortical* and *medullary* substance ; the latter being arranged in separate conical masses named *pyramids of Malpighi* with their broad bases (*b*, *b*) directed towards the surface, and their points towards the sinus, where they form prominent *papillæ*. The pyramids are embedded in the cortical substance, which separates them from each other, and encloses them everywhere except at the papillæ, which emerge from it and project into the sinus.

The external or cortical substance (*a*) is situated immediately within the fibrous capsule, and forms the superficial part of the organ throughout its whole extent to the depth of about 4 mm., and moreover sends prolongations inwards (*septula renum* or *columnæ Bertini*) between the pyramids as far as the sinus and bases of the papillæ. It is of a nearly uniform light crimson-brown appearance, and is soft and easily lacerated in directions vertical to the surface. The medullary portion of the kidney is more dense than the cortical, and is distinctly striated, owing to its consisting of small diverging uriniferous tubes, and to its blood-vessels being arranged in a similar manner. There are generally more than twelve pyramids, but

their number is inconstant, varying from eight to eighteen. Towards the papillæ the pyramids are of a lighter colour than the cortical substance, but at their base they are usually purplish and darker.

Excretory apparatus.—On squeezing a fresh kidney which has been split open, a little urine will be seen to drain from the papillæ by fine orifices on their surface. The secretion is carried away and conveyed into the bladder by the ureter. This long tube on being traced up to the kidney is seen to be somewhat enlarged, and then to expand as it enters the hilum, into a large funnel-shaped dilatation named the *pelvis* (fig. 208, P). This, within the sinus, divides usually into three, but sometimes only two primary tubular divisions, and these at length end in a larger number of short, truncated but comparatively wide branches named *calices* or *infundibula*, which receive the papillæ into their wide mouths and are attached



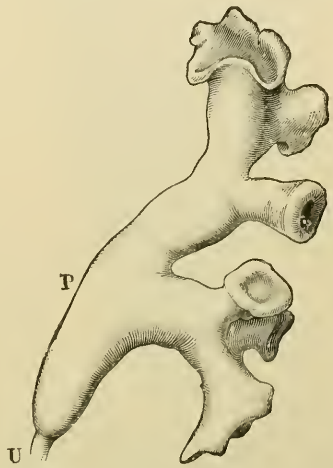


Fig. 207.—Plan of a longitudinal section through the pelvis and substance of the right kidney. One-half the natural size.

a, the cortical substance ; *b*, *b*, broad part of two of the pyramids of Malpighi ; *c*, *c*, the divisions of the pelvis named calices, or infundibula, laid open ; *c'*, one of these unopened ; *d*, *d*, summit of the pyramids or papillæ projecting into calices ; *e*, *e*, section of the narrow part of two pyramids near the calices ; *p*, pelvis or enlarged portion of the ureter within the kidney ; *u*, the ureter ; *s*, the sinus ; *h*, the hilum.

Fig. 208.—Cast of the interior of the upper end of the ureter. (Henle.)

P, pelvis ; U, ureter.

around the bases of those prominences from which, of course, they catch the issuing urine.

A single calix often surrounds two, sometimes even three papillæ, which are in that case united together ; hence, the calices are in general not so numerous as the papillæ. The spaces between the calices are occupied by a considerable amount of fat, imbedded in which are seen the main branches of the renal vessels.

Like the rest of the ureter, the pelvis and greater part of the calices consist of three coats, viz., a strong external fibrous and elastic tunic, which becomes continuous around the bases of the papillæ with that part of the proper coat of the kidney which is continued into the sinus ; secondly, a thin internal mucous coat, which, or at least its epithelium, is reflected over the summit of each papilla ; and thirdly, between these two, a double layer of muscular fibres, longitudinal and circular. The longitudinal fibres are lost near the extremity of the calix, but the circular fibres, according to Henle, form a continuous circular muscle round the papilla where the wall of the calix is attached to it.

The pyramidal masses found in the adult kidney indicate the original separation of this gland into lobules in the earlier stages of its growth. Each of these

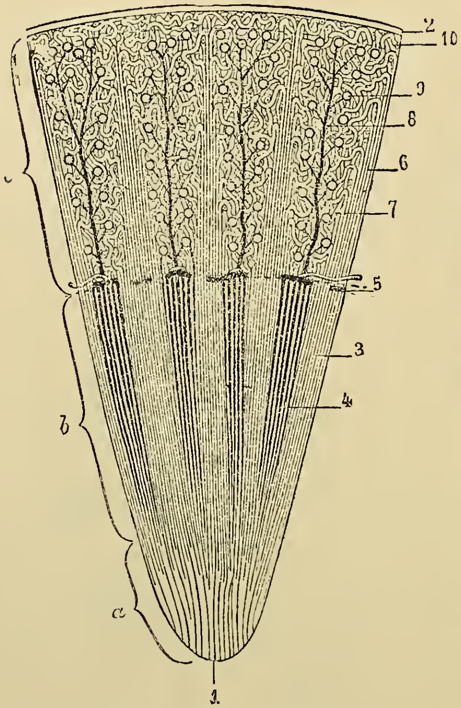


Fig. 209.—Diagram of a section through part of the kidney parallel to the medullary tubules. (Testut.)

a, papillary zone ; *b*, boundary zone ; *c*, cortical zone. 1, apex of papilla ; 2, capsule ; 3, clear striæ of boundary zone, formed by tubules of medulla ; 4, dark striæ of boundary zone formed by vasa recta ; 5, vascular arches ; 6, medullary rays ; 7, labyrinth ; 8, interlobular vessels ; 9, Malpighian corpuscles ; 10, subcapsular layer.

primitive lobules is in fact a pyramid surrounded by a proper investment of cortical substance, and is analogous to one of the lobules of the divided kidneys seen in many mammals. As the human kidney continues to be developed, the adjacent surfaces of the lobules coalesce and the gland becomes a single mass ; the contiguous parts of the originally separate cortical investments, being blended together, form the partitions between the pyramids already described. Moreover, upon the surface of the kidney even in the adult, after the removal of the fibrous capsule, faintly marked furrows may be traced on the cortical substance, opposite the intervals in the interior between the several Malpighian pyramids ; and not unfrequently instances occur in which a deeper separation of the original lobules by grooves remains apparent in the adult kidney.

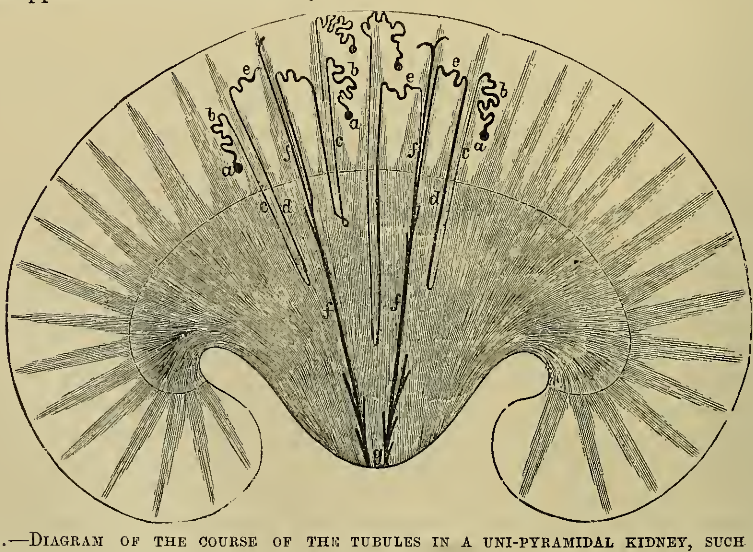


Fig. 210.—Diagram of the course of the tubules in a uni-pyramidal kidney, such as that of the rabbit. (Toldt.)

a, Malpighian bodies ; *b*, first convoluted tubule ; *c*, *d*, looped tubule of Henle ; *e*, second convoluted tubule ; *f*, collecting tube ; *g*, ducts of Bellini.

Tubuli uriniferi.—On examining the summit of one of the papillæ carefully, especially with the aid of a lens, a number of small orifices may be seen varying in diameter from 0·06 to 0·12 mm. They are frequently collected in large numbers at the bottom of a slight depression or *foveola* found near the summit of the papilla, but most commonly the surface is pitted over with about a score of small depressions of this sort. On tracing these minute openings into the substance of the pyramids,

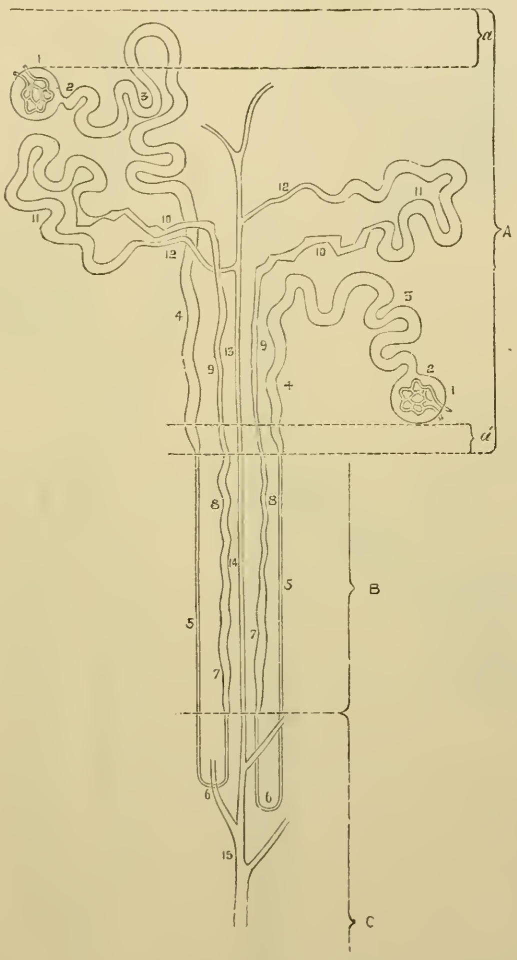


Fig. 211.—Diagram of the course of two uriniferous tubules. (Klein.)

A, cortex ; B, boundary, zone C, papillary zone of the medulla ; *a*, *a'*, superficial and deep layers of cortex, free from glomeruli. For the explanation of the numerals, see the text (p. 197).

they are discovered to be the mouths of small tubes or ducts, the *uriniferous tubes* before mentioned, which thus open upon the surface of the several papillæ into the interior of the calices.

As these tubules pass up into the pyramidal substance, they bifurcate again and again at very acute angles, their successive branches running close together in straight and slightly diverging lines, and they continue thus to divide and subdivide until they reach the sides and bases of the pyramids, whence they pass, greatly augmented in number, into the cortical substance. In the cortical part the straight tubules belonging to a Malpighian pyramid are continued for some way, in several

groups or bundles, the tubules in the centre of which approach nearer the surface than those at the sides. These bundles are known as the *medullary rays* (fig. 209, 6)

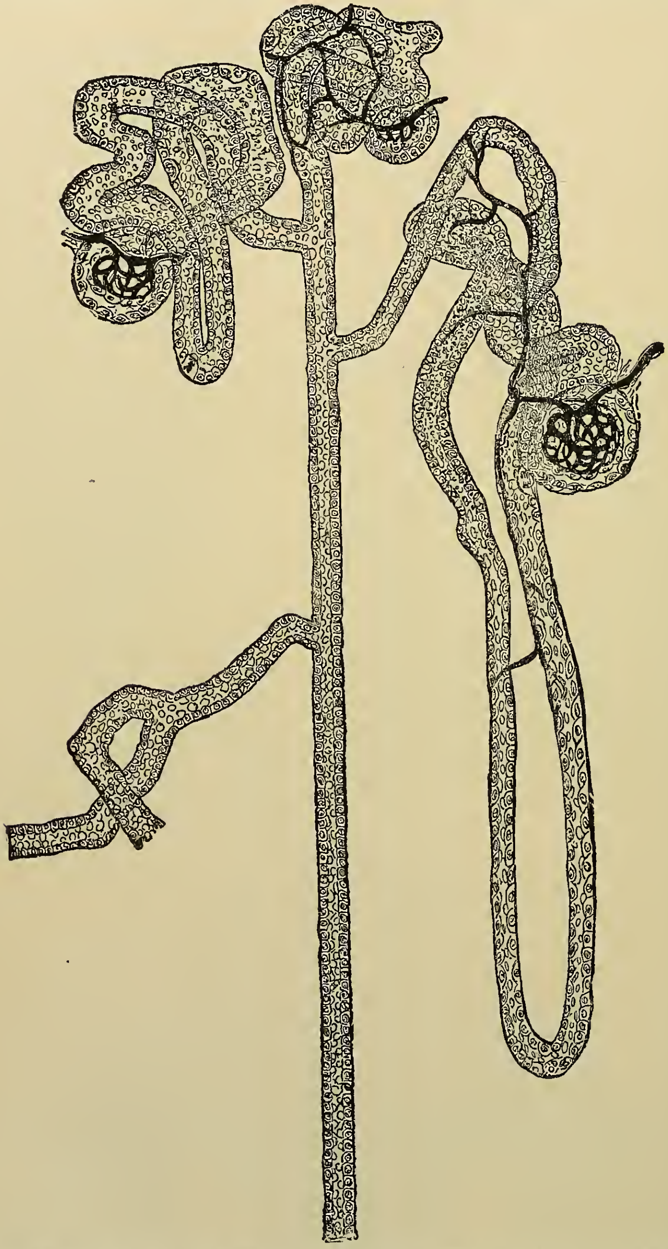


Fig. 212.—Three malpighian corpuscles and uriniferous tubules of a young mammal showing three stages of formation of the looped tubules, and the adherence of the beginning of the second convoluted tubes to the malpighian corpuscles. (Golgi.)

of the cortex, and the cortical substance between and around them is termed, on account of the intricate arrangement of its tubules, the *labyrinth of the cortex* (7).

The part of the pyramid which is nearest the cortical substance contains a number of pencil-like bundles of small blood-vessels, which originating from arterial

and venous arches at the junction of cortex and medulla, dip into the pyramid, and thus commence the separation of its tubules into the bundles which are continued into the cortex as the medullary rays. The portion of the pyramid which is thus broken up is termed the *boundary zone* (fig. 209, *b*).

Course of the tubules.—Each tube commences in the labyrinth of the cortical substance by a spherical dilatation enclosing the vascular Malpighian tufts to be afterwards described.

Emerging from this dilatation (fig. 211, 1), which is known as the *capsule* (2), the tubule is at first convoluted and wide (*first convoluted tubule*, 2, 3), but on approaching the medullary ray it becomes nearly straight with a slight tendency to a spiral (*spiral tubule* of Schachowa, 4). At the junction of cortex and medulla the spiral tube rapidly narrows and passes straight down through the boundary zone towards the apex of the pyramid (5). After a shorter or longer course, however, it loops upwards again (6) becoming enlarged in the boundary zone (7), but somewhat smaller again above this (8, 9) where it passes again up the medullary ray. The part of the uriniferous tube which thus dips down towards the papilla and turns upwards again is known as the *looped tubule of Henle*. On emerging from the medullary ray the tubule is characterized by great irregularity of outline (*irregular tubule*, 10)

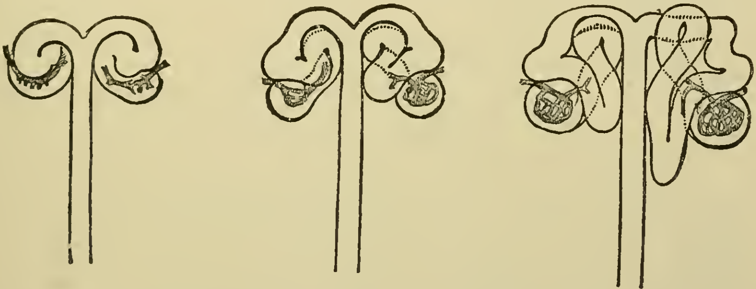


Fig. 213.—Diagram showing several phases of development of the uriniferous tubule. (Golgi.)

before again becoming convoluted (*second convoluted tubule*, 11). Finally this last is connected with one of the collecting tubules of the medullary ray by a small *junctional tubule* (12), and the *collecting tubes* (13, 14, 15) uniting with one another, as already noticed, become gradually larger as they pass to open as *excretory tubes* at the summit of the papilla (fig. 210).

According to the observations of Golgi, the Malpighian corpuscle of each uriniferous tube is always intimately adherent to a part of the tube near the commencement of the second convoluted tubule (fig. 212), and has retained this adhesion from its earliest appearance in the embryo, when the tube is an S-shaped projection from the collecting tube. For of the three limbs of the S, the lowermost embraces the glomerulus, and forms the Malpighian corpuscle: the middle one develops into the first convoluted tube, and all the parts of the tube of Henle (including the spiral and irregular tubes) while the upper part of the S forms the second convoluted and junctional tubes (figs. 212, 213).

Structure of the tubules.—The tubules consist in every case of a basement membrane and epithelium, but the character of the latter as well as the size of the tubes varies considerably in the different parts.

The *capsule* (fig. 216, *a*) is lined by a layer of flattened cells, which is reflected over the contained tuft of blood-vessels, dipping between the separate bunches of which this is composed. This layer is much more easily recognized in the fœtus and young subject than in the adult (fig. 215). At the commencement

of the convoluted tubule and sometimes, as in the mouse, even in the part of the Malpighian corpuscle nearest the tubule, the epithelium becomes cubical. It has been stated by Hassall (various mammals), and by Klein (mouse) that the epithelium here is provided with cilia, but the statement requires confirmation. In lower vertebrates, as in the frog, the existence of cilia in this place has long been known.

The *first convoluted tubule* has an epithelium of a peculiar character (Heidenhain). The part of the cell which encloses the nucleus is composed of ordinary granular-looking protoplasm, but the part next to the basement membrane is chiefly made up of straight or nearly straight rods or fibrils placed vertically to the basement membrane and extending a variable distance towards the

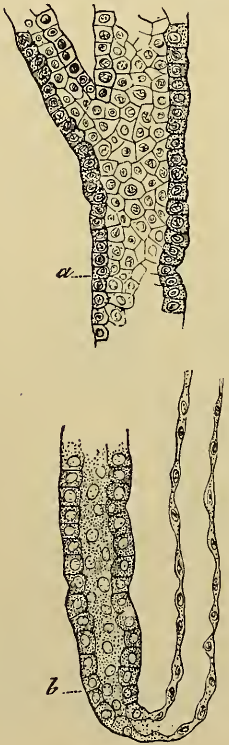


Fig. 214.—Portions of kidney tubules (isolated). (Cadiat.) *a*, large collecting tubule ; *b*, loop of Henle.

lumen (figs. 216, 217), but usually occupying the greater part of the cell, although there is always a stratum of homogeneous or granular substance bounding the cell towards the lumen. The nucleus is spherical. The cells are with difficulty separated from one another, at least in some animals (*e.g.*, dog), owing to their possessing lateral ridge-like processes (fig. 217, *e* ; fig. 218) which interlock with one another (Schachowa).

The *spiral tubule* of Schachowa is the continuation of the convoluted tubule into the medullary ray, and possesses a similar epithelium (fig. 216, *e*). Towards its termination, however, the cells become shorter and less distinctly fibrillated, but split up more completely at their borders into ridges with intervening furrows, especially in the part of the cell next to the basement membrane, so that the cells bear somewhat the aspect of columns deeply fluted at their base. Between these fluted cells, others of clearer aspect are found fitting in, and having an expanded base which extends partly underneath them. According to Schachowa they are present also in the convoluted tubules proper.

In the narrow tube which forms the *descending limb of Henle's loop*, the epithelium is quite low, and flattened against the basement membrane. The protoplasm is clear and the nucleus prominent. The ridge-like processes at the base of the cells are said not to be altogether absent even here.

The *loop of Henle* has an epithelium similar in character to that of the descending limb.

In the *ascending limb* of the looped tubule the epithelium again takes on the character which is exhibited in the first convoluted and spiral tubes, but the cells are rather smaller, the lumen of the tube relatively larger, and the intracellular rods not so long as in those tubes. The cells of this segment are sometimes set obliquely so as to overlap one another. In the human subject they contain brown pigment-granules (Klein). This tubule is apt to exhibit a spiral character. It is divisible into three parts, viz., a lowermost tapering part, a part in the boundary zone (fig. 211, 7, 8) which is the largest, and a part in the cortical zone (9) which is narrow and has strongly rodded epithelium, and may be looked upon as the commencement of the next tubule.

In the *irregular tubules* the rod-like structure of the cells is very distinct (fig. 216, *b*). The cells are very unequal in size, the irregularity of the tubules

being thus compensated, and the lumen rendered nearly the same throughout. The nucleus is oval. These tubules are said to lack a basement membrane.

The *second convoluted tubule* (*intercalary tube*, Schweigger-Seidel) is like the first in size, but has a different kind of epithelium. The cells, which are rather long,

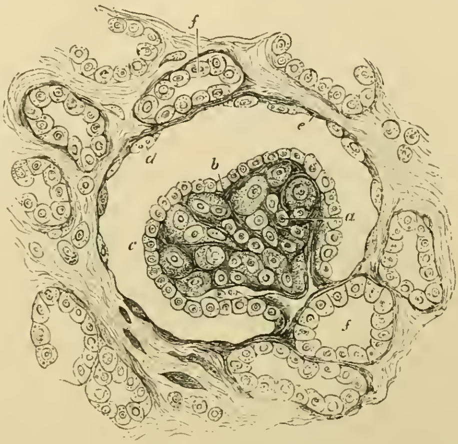


Fig. 215.—Section of cortical substance of kidney: human fœtus. Highly magnified. (Klein.)

a, glomerulus with blood-vessels not fully developed; *b*, connective tissue between the blood-vessels; *c*, epithelium covering it continuous with *d*, flattened epithelium lining Bowman's capsule; *f*, *f*, convoluted tubes.

with a relatively large nucleus, present a peculiar highly refractive appearance, and where they rest on the membrana propria, the protoplasm exhibits projections which fit between those of neighbouring cells.

The *junctional tubule*, which unites the last-named to the collecting tubes, is narrow, but its lumen is relatively large. It is lined by clear flattened or cubical cells; but between them some cells are found which are similar in appearance to the cells which line the segment just described.

Fig. 216.—Tubules from a section of the dog's kidney. (Klein and Noble Smith.)

a, Capsule, enclosing the glomerulus; *n*, neck of the capsule; *c*, *c*, convoluted tubules; *b*, irregular tubules; *d*, collecting tube; *e*, *e*, spiral tubes; *f*, part of the ascending limb of Henle's loops here (in the medullary ray) narrow.

The *collecting tubes*, which are characterised by their straight course and very distinct lumen (fig. 216, *d*), are lined by a clear cubical epithelium, the cells of which are at first somewhat irregular, but become longer and more regular as the tubes approach the papilla.

In the larger *collecting* or *excretory tubes* (*ducts of Bellini*) the form of the cells is typically columnar, modified only by the form of the surface which they cover. In these largest tubes the basement membrane is said to be absent, the epithelium cells resting directly upon the connective tissue.

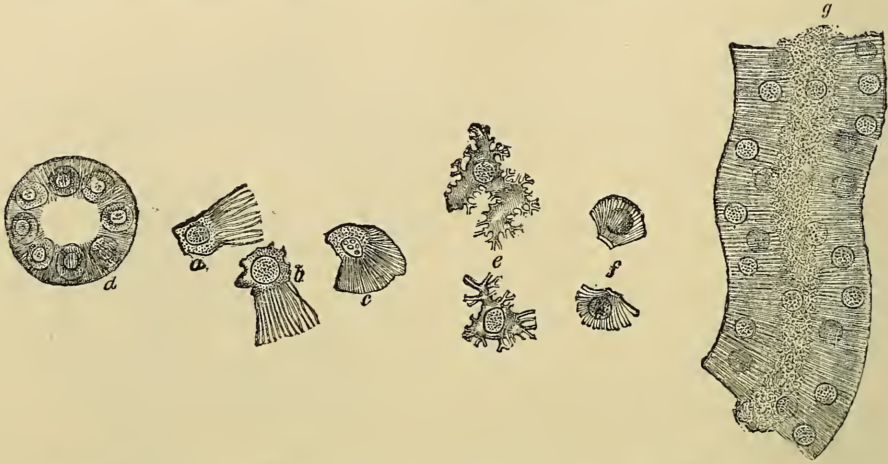


Fig. 217.—To illustrate the structure of the epithelium of the convoluted tubules (from Heidenhain).

d, section of a convoluted tubule from the rat, showing the unaltered protoplasm occupying a circular area around the nucleus of each cell; *a*, *b*, *c*, isolated cells from the convoluted tubules of the rat; *e*, isolated cells from the dog's kidney, viewed from the inner surface, and showing the irregular contour of the protoplasm; *f*, isolated cells from the newt, showing the rods and the homogeneous cuticular layer; *g*, longitudinal optical section of part of a convoluted tubule from the dog's kidney.

The characters of the epithelium in the several parts of a uriniferous tube may be thus concisely stated, viz., *clear flattened cells* in the capsule, the descending part of Henle's loop and the loop itself; *granular-looking rodded epithelium* with

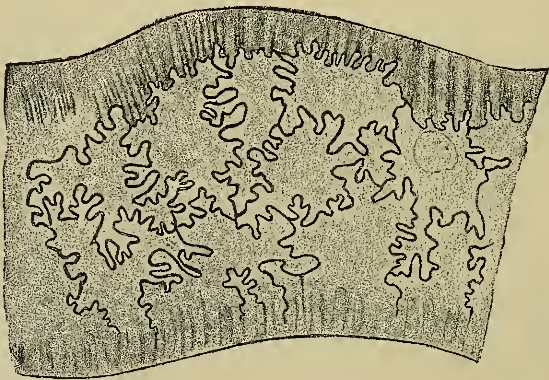
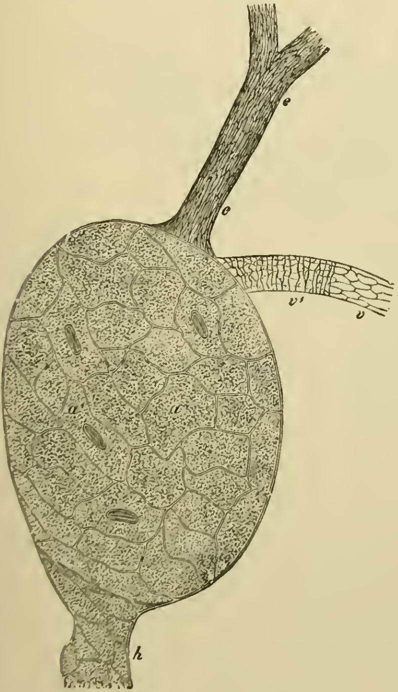


Fig. 218.—Portion of a convoluted tube from the kidney, showing the irregularly fluted outlines of the cells. (Landauer.)

fluted interlocking borders in the convoluted tubules, the spiral tubules, the ascending limb of Henle's tubule, and in the irregular tubule; *clear cubical or columnar cells* in the junctional tubule, the collecting tubules, and the ducts of Bellini.

Klein describes a very delicate nucleated membrane lining the tubules within the epithelium, in all the tubes except the descending limb of Henle's loop, and in the loop itself.

Blood-vessels.—The kidneys are highly vascular, and receive their blood from the renal arteries, which are very large in proportion to the size of the organs they supply. Each renal artery divides into four or five branches, which, passing in at the hilum, between the vein and ureter, may be traced into the sinus of the kidney, where they lie amongst the infundibula, together with which they are usually embedded in a quantity of fat. Penetrating the substance of the organ between the papillæ, the arterial branches enter the cortical substance which intervenes between the pyramids of Malpighi, and proceed in this, accompanied by a sheathing of areolar tissue, and dividing and subdividing, to reach the bases of the pyramids, where they form *arterial arches* between the cortical and medullary parts, which however are not complete, and in this respect differ from the freely anastomosing *venous arches* which accompany them. From the



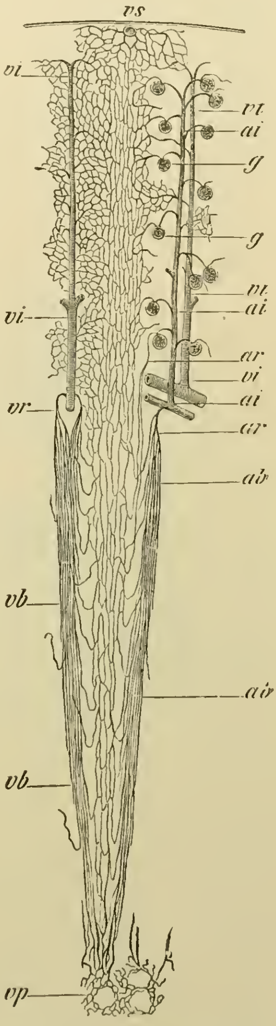


Fig. 219.—MALPIGHIAN CORPUSCLE FROM THE RABBIT'S KIDNEY: NITRATE OF SILVER PREPARATION. HIGHLY MAGNIFIED. (Ludwig.)

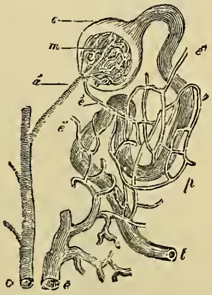
v, vas afferens, showing its epithelial lining: at *v'*, the transverse muscular fibres are also seen; *e*, vas efferens; *a*, *a'*, basement membrane of capsule with epithelioid markings, passing at *h* into that of the commencing uriniferous tubule.

Fig. 220.—DIAGRAM OF THE DISTRIBUTION OF THE BLOOD-VESSELS IN THE KIDNEY (from Ludwig).

ai, *ai*, interlobular arteries; *vi*, *vi*, interlobular veins; *g*, a glomerulus; *vs*, stellate vein; *ar*, *vr*, arteriæ et venæ rectæ forming pencil-like bundles, *ab*, *vb*; *vp*, venous plexus in the papillæ.

arches peripheral branches (*arteriæ interlobulares* (fig. 220, *ai*)) are given off, which pass outwards between the medullary rays and amongst the convoluted tubules, pursuing a nearly straight course towards the surface of the organ. As they proceed

they give off at intervals short and usually curved branches (*arteriæ glomerulorum*) which proceed without further division to the dilated ends of the uriniferous tubules. Within the capsule the small artery (*vas adferens*) breaks up into a larger number of capillary vessels which have a convoluted arrangement, and are closely held together by connective tissue to form a spheroidal vascular tuft, the *glomerulus* of Malpighi. A vein (*vas efferens*) smaller than the artery, emerges from the glomerulus close to the point where the artery enters; but, instead of joining with other small veins to form larger venous trunks, as is the case in other organs, the efferent vessel divides into branches after the manner of an artery, and from these arises a dense network of capillaries which everywhere ramify over the walls of the uriniferous tubules (fig. 221), the meshes of the network being polygonal amongst the convoluted tubules and elongated amongst the tubules of the medullary rays. But the efferent vessels from the lowermost glomeruli break up wholly into pencils of straight vessels (*pseud-arteriæ rectæ* (fig. 220, *vr*: fig. 223, *ef*)) which pass directly



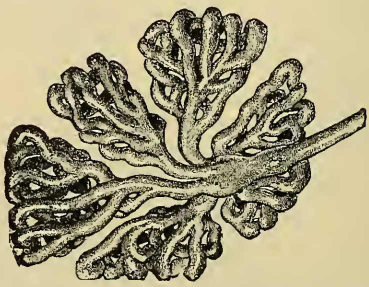


Fig. 221.—Diagram showing the relation of the uriniferous tubules to the blood-vessels (after Bowman).

a, one of the interlobular arteries; *a′*, afferent artery passing into the glomerulus; *c*, capsule of the glomerulus; *t*, convoluted tube; *e′*, *e′*, efferent vessels which subdivide in the plexus *p*, surrounding the tube, and finally terminate in the interlobular vein, *c*.

Fig. 222.—Lobules of glomerulus of pig's kidney. (Ludwig.)

into the boundary layer of the medulla, and there supply the continuation downwards of the medullary rays into the pyramid.

The renal arteries give branches likewise to the capsule of the kidney which anastomose with branches of the lumbar arteries, and that so freely that Ludwig was able partially to inject the kidneys of a dog from the aorta after the renal arteries had been tied.

The blood is conveyed from the cortex of the kidney by veins (*venæ interlobulares*) which accompany the interlobular arteries, and join the convex side of the venous arches which lie between the medulla and cortex, and also by veins which lie close beneath the capsule of the organ, and take origin by the convergence of minute venous radicles, so as to present a stellate appearance (*venæ stellulæ*). These vessels, which receive blood from the capsule of the kidney, pass inwards through the cortex and also join the venous arches.

With the exception of the blood brought by the false arteriæ rectæ the blood supply of the medulla is to a great extent independent of that of the cortex, although of course the capillary network is continuous throughout. The pyramids are chiefly provided with blood by branches which come off directly from the concave side of the arterial arches, and passing down into the boundary layer of the medulla there divide to form bunches or pencils of parallel or slightly diverging minute vessels (*arteriæ rectæ*, fig. 220, *ar*), which by alternating with the bundles of uriniferous tubules which are passing up to the cortex to form the medullary rays, produce the characteristic streaked appearance of this part of the pyramid (see fig. 209).

The long meshed capillary network which is supplied by the arteriæ rectæ is continued down to the apex of the papilla. Here the veins of the pyramid commence in a close plexus of small venous radicles surrounding the excretory ducts near their orifices (fig. 220, *vp*). Passing outwards towards the base of the pyramid, and receiving lateral branches at acute angles from its capillary network, the same veins become collected together into pencils, the vessels of which (*venæ rectæ*) are intermixed with the arteriæ rectæ, and unite into vessels which open into the concave side of the venous arch.

The venous trunks thence proceed, in company with the arteries, through the cortical septula between the pyramids, to the sinus of the kidney. Joining

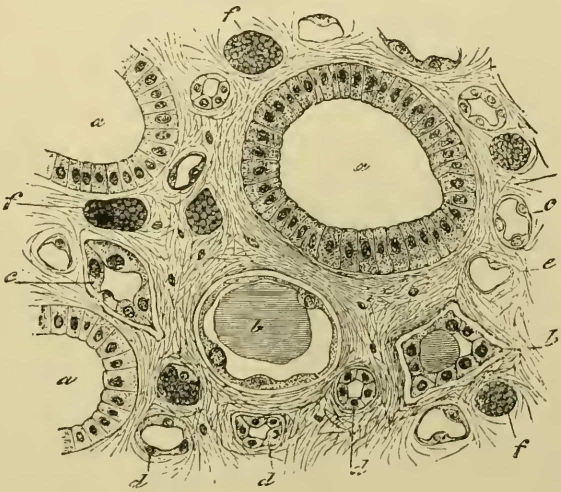


Fig. 223.—Injected glomerulus from the inner part of the cortical substance of the horse's kidney. 70 diameters (from Kölliker after Bowman).

a, interlobular artery ; *af*, afferent vessel ; *m*, *m*, convoluted vessels of the glomerulus ; *e f*, efferent vessel ; *b*, its subdivision in the medullary substance.

Fig. 224.—Section across a papilla of the kidney. (Cadiat.)

a, ducts of Bellini ; *b*, *c*, *d*, tubes of Henle, ascending and descending ; *c*, *f*, blood-capillaries.

together, they escape from the hilum, and ultimately form a single vein, which lies in front of the artery, and ends in the inferior vena cava.

Lymphatics.—The lymphatics of the kidney are numerous, consisting of a superficial set forming a plexus in the fibrous capsule, and of deep lymphatics which issue from the hilum with the blood-vessels. Ludwig and Zawarykin showed that there exists a network of freely intercommunicating lymphatic spaces between the tubules, in communication both with the lymphatics of the surface and those which issue with the blood-vessels at the hilum. They are most abundant in the cortical substance.

Nerves.—The nerves which have been traced into the kidneys are small. They come immediately from the *renal plexus* and the *lesser splanchnic* nerves, and contain filaments derived from both the sympathetic and cerebro-spinal systems. They may

be traced accompanying the arteries as far as their finer branches, and some fibrils ramify over and amongst the uriniferous tubules, but it is uncertain how they end.

Intertubular stroma.—Between the tubules and vessels of the kidney, although they are disposed closely together, a small amount of interstitial connective tissue is found. It has a more fibrous character in the vicinity of the chief ramifications of the blood-vessels, and also around the Malpighian corpuscles, and the tubes of the medullary substance. It is more abundant in the neighbourhood of the papillæ than in other parts of the kidney substance (fig. 224).

THE URETERS.

The ureters are the two tubes which conduct the urine from the kidneys into the bladder. The dilated commencement of each called the *pelvis,* which is partly situated in the sinus of the kidney, and into which the calices pour their contents, has already been described. Towards the lower end of the hilum of the kidney the pelvis becomes gradually contracted, and opposite the lower end of the gland assuming the cylindrical form receives the name of *ureter.*

The ureters measure from fourteen to sixteen inches in length ; their ordinary width is that of a goose-quill. They are frequently, however, dilated at intervals, especially near the lower end. The narrowest part of the tube, excepting its orifice, is that contained in the walls of the bladder.

Each ureter passes at first obliquely downwards and inwards to enter the cavity of the true pelvis, and then turns forwards and inwards to reach the base of the bladder. In its whole course it lies close behind the peritoneum, and is connected to neighbouring parts by loose areolar tissue. Superiorly it rests upon the psoas muscle and is crossed very obliquely from within outwards by the spermatic vessels which descend in front of it. The right ureter passes close to the outer side of the inferior vena cava, and often gets in front of this vessel. Lower down the ureter passes either over the common iliac or the external iliac vessels, behind the termination of the ileum on the right side, and behind the sigmoid colon on the left. Descending into the pelvis it lies beneath the layer of peritoneum forming the corresponding posterior false ligament of the bladder, and reaching the side of the bladder near the base (fig. 227, *u*), runs downwards and forwards in contact with it, below the obliterated hypogastric artery, and is crossed upon its inner side in the male by the vas deferens (*i*) which passes down between the ureter and the bladder. In the female the ureter runs along the side of the cervix uteri and upper part of the vagina. According to Holl at the level of the origin of the obturator, vesical, and uterine arteries it begins to describe a bow-shaped curve three and three-fifths of an inch long, which extends to the bladder. This curved portion is crossed at the level of the external os uteri by the uterine artery which is separated from the ureter by a venous plexus. Here it lies three-fifths of an inch external to the cervix. It then passes on to the side wall of the vagina and near where it pierces the bladder lies between this organ and the anterior vaginal wall.

Having arrived at the base of the bladder about two inches apart from one another the ureters enter its coats, and running obliquely through them for about three-quarters of an inch, open at length upon the inner surface by two narrow and oblique slit-like openings. When the bladder is distended these openings are situated about an inch-and-a-half from the urethral orifice, and about the same distance from one another. This oblique passage of the ureter through the vesical walls, while allowing the urine to flow into the bladder, has the effect of preventing its reflux.

Varieties.—Sometimes there is no funnel-shaped expansion of the ureter at its upper end into a pelvis, but the calices unite into two or more narrow tubes, which afterwards coalesce

to form the ureter. Occasionally the separation of these two tubes continues lower down than usual, and even reaches as low as the bladder, in which case the ureter is double. In rare cases a triple ureter has been met with. Several instances are recorded in which a supernumerary ureter, proceeding from the upper part of the kidney, opened directly into the urethra.

The right ureter has been seen passing behind the inferior vena cava, and then turning forwards between that vessel and the aorta (Hochstetter, Morph. Jahrb., xxi, 636).

In instances of long-continued obstruction to the passage of the urine, the ureters may become enormously dilated.

Structure.—The walls of the ureter are pinkish or bluish white in colour. They consist of an external fibrous coat, a middle coat of plain muscular tissue, and a mucous lining. The muscular coat possesses two layers of longitudinal fibres and a middle circular layer.

The **mucous membrane**, thin and smooth, presents a few longitudinal folds when the ureter is laid open. It is composed of areolar tissue which becomes gradually loose towards the muscular coat, but there is no marked distinction into mucous and submucous layers. It is prolonged above to the papillæ of the kidney, and below becomes continuous with the lining membrane of the bladder. The epithelium (fig. 225) is of a peculiar character, like that of the bladder. It is stratified, con-

Fig. 225.—Epithelium from the pelvis of the human kidney. (Kölliker.) 350 diameters.
A, different kinds of epithelial cells separated ; B, the same in situ.

sisting of four layers (fig. 225, B, in section), in the uppermost of which the cells are somewhat cubical, with depressions on their under surface, which fit upon the rounded ends of a second layer of pear-shaped cells ; then follow two layers of rounded or oval cells, with processes extending down to the mucous membrane. This description of the shape of the epithelium cells applies to them as they occur in the empty condition of the duct, but in the distended state the superficial cells are flattened out, and the pear-shaped and oval cells are much shorter. All the cells are connected by "cell-bridges" with one another as in a stratified epithelium. The superficial cells usually have two nuclei, and are believed to divide by "amitosis." The deeper cells multiply on the other hand by karyokinesis.

A few small mucous glands have occasionally been described at the upper end of the ureter and in the renal pelvis, but they appear not to be present in man. Epithelial downgrowths are occasionally found both here and in the urinary bladder, and these may occasionally have been taken for glands (v. Brunn). Mucus is however secreted by the lining epithelium. Lymphoid nodules have been met with in the mucous membrane of the pelvis of the kidney.

Vessels and Nerves.—The ureter is supplied with blood from small branches of the *renal*, the *spermatic*, the *internal iliac*, and the *inferior vesical* arteries. The veins end in various neighbouring vessels. The nerves come from the *inferior mesenteric*, *spermatic*, and *hypogastric plexuses*. They form plexuses in the outer and muscular coats containing a few ganglion-cells.

THE URINARY BLADDER.

The urinary bladder (vesica urinaria) is a hollow receptacle for the urine, having an average capacity of about a pint when moderately filled, but capable of being distended to a considerably greater degree.

The average capacity of the bladder is often stated to be greater in the female than in the male; and, no doubt, instances of very large female bladders are not unfrequent; but these have probably been the result of unusual distension : in the natural condition, according to Luschka and Henle, the female bladder is decidedly smaller than that of the male.

The size, shape, and position of the bladder and its relations to neighbouring parts vary according to the degree of distension of its cavity, and also, when empty,

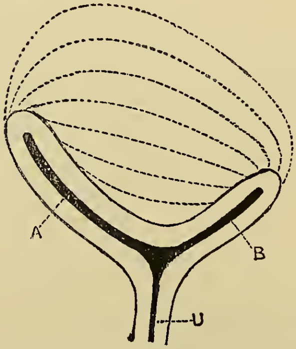


Fig. 226.—Diagram of median section of empty diastolic bladder and adjacent part of urethra. (J. S.)

A, anterior limb of bladder ; P, its posterior limb ; U, urethra. The dotted lines show the changes in the shape of the bladder during its distension.

according to the condition of its muscular coat, whether contracted or relaxed. When empty and relaxed (in diastole) it lies deeply in the pelvis, and in a vertical median section its cavity, with that of the adjacent portion of the urethra, is Y-shaped, the stem of the Y being formed by the urethra, and its two limbs by the bladder. Of the two limbs the *anterior* is the longer, and is directed upwards and forwards, while the shorter *posterior* limb passes backwards and upwards. The empty diastolic bladder has three surfaces—a *superior*, with its concave

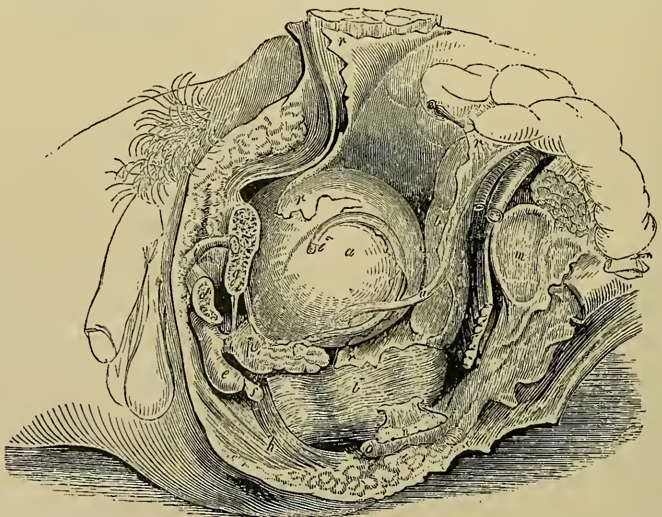


Fig. 227.—Lateral view of the viscera of the male pelvis. (R. Quain.) $\frac{1}{4}$

The left hip-bone has been disarticulated from the sacrum, the spinous process of the ischium cut through, and the pubis divided to the left of the symphysis ; *a*, bladder ; *b b′*, rectum ; *c*, membranous part of the urethra ; *d*, section of the left corpus cavernosum ; *e*, bulb of the spongy body of the urethra ; *f*, Cowper's gland ; *g*, section of the body of the pubis ; *h*, sphincter ani muscle ; *i*, part of the left vas deferens ; *m*, articular surface of the sacrum ; *n*, divided spine of the ischium ; *o*, coccyx ; *p*, prostate gland ; *r*, *r*, peritoneum ; *r′*, recto-vesical pouch ; *u*, left ureter ; *v*, left vesicula seminalis.

upper aspect covered by peritoneum, an *anterior*, lying above the pubo-prostatic ligaments, and behind the pubic symphysis, and a *posterior*, which is in relation

with the rectum, vasa deferentia, and vesiculæ seminales in the male, and the cervix of the uterus and upper part of the vagina in the female. Both the anterior and posterior surfaces are uncovered by peritoneum.

On the other hand, when the bladder is empty and contracted (in systole) the two limbs of its cavity are much shortened, its mucous membrane is thrown into

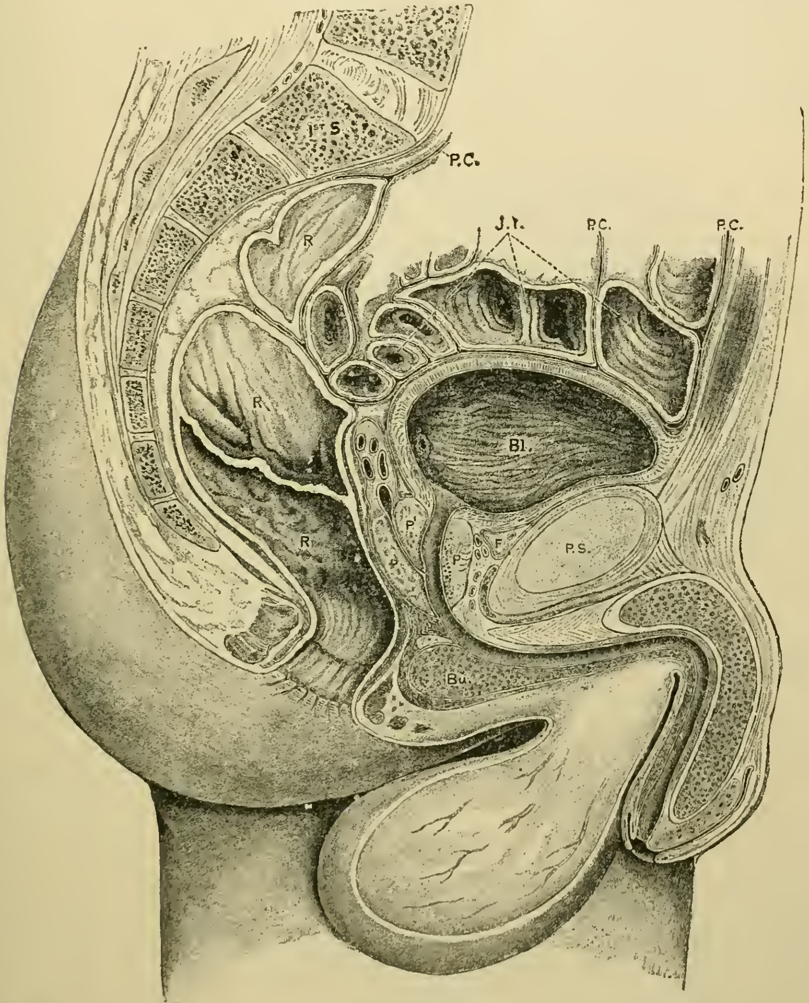


Fig. 228.—Vertical median section of the pelvis of an adult male subject. (Braune.) ½

1st s, body of 1st sacral vertebra; P. S., pubic symphysis; Bl., bladder; R, R, R, rectum; P, P, prostate; P′, middle lobe of prostate; F, retro-pubic pad of fat; Bu., bulb; P. C., peritoneal cavity; J. I., convolutions of jejuno-ileum.

numerous folds, its muscular coat is greatly thickened, and its superior aspect is rounded and convex. As the relaxed bladder is gradually filled with urine it expands chiefly in an upward direction, its superior surface being separated from the anterior and posterior surfaces, and becoming convex towards the peritoneal cavity. When moderately filled it is still contained within the pelvic cavity, and has a rounded form (fig. 227, *a*), but when completely distended it rises above the brim of the pelvis, and becomes egg-shaped; its larger end, which is called the

base, or *fundus*, being directed downwards and backwards towards the rectum in the male and the vagina in the female; and its smaller end, or *summit*, resting against the lower part of the anterior wall of the abdomen. Immediately in front of the base is the portion which joins the urethra, and is often named the *cervix*, or *neck*. When the bladder is excessively distended (fig. 229) it may rise into the abdomen nearly as high as the umbilicus, and it also sinks somewhat in the pelvis, pushing the prostate and lower end of rectum downwards and backwards. The long axis of the distended bladder varies in different cases, being modified by the degree of distension of the bladder itself, as well as that of

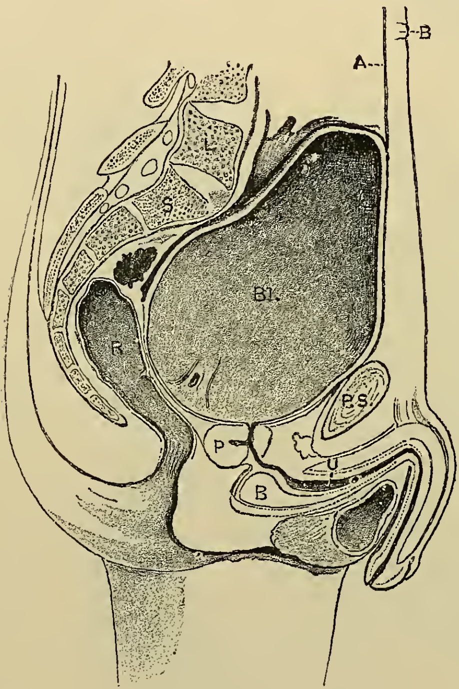


Fig. 229. Median section of the pelvis of an adult male subject. (Rüdinger.)

L. body of 5th lumbar vertebra; S, body of 1st sacral vertebra; P, S, pubic symphysis; P, prostate; B, bulb of corpus spongiosum; U, urethra; B, umbilicus; A, peritoneum. The reflection of the peritoneum from the anterior abdominal wall on to the bladder is higher than normal.

the rectum and other portions of the intestine that may be in relation with it. In a section of Braune's (see fig. 228), in which the bladder was moderately distended, it is almost horizontal, while in one by Rüdinger (see fig. 229), in which the bladder was greatly distended, it is rather more nearly vertical than horizontal. While in the male the longest diameter of the moderately distended bladder is directed from its base to its summit, in the female the transverse diameter is the longest.

Connections and Relations.—While freely movable in all other directions, the bladder is fixed to the walls of the pelvis in the neighbourhood of the urethral orifice, its mucous and muscular coats being here continuous with those of the prostatic portion of the urethra, while its fibrous investment is connected with the pelvic wall by bands of fibrous tissue, called the true ligaments of the bladder (see Vol. II., Pt. 2). It is supported, moreover, by strong areolar connections with the rectum and prostate or uterus and vagina, according to the sex, in a slighter degree by the two ureters, the obliterated hypogastric arteries, and the urachus, by numerous blood-vessels, and, lastly, by a partial covering of the peritoneum, which, in being reflected from this organ in different directions, forms duplicatures, named the *false ligaments* of the bladder.

The **antero-inferior** or **pubic surface** is entirely destitute of peritoneum, and is in apposition with the *recto-vesical fascia*, the symphysis and body of the pubis, and, if the organ be full, the lower part of the anterior wall of the abdomen. It is connected to these parts by loose areolar tissue. The lower part of this surface, close to where it joins the prostate, is attached to the back of the pubis by two strong bands of the recto-vesical fascia, named the *anterior true ligaments*. This surface of the distended bladder may be punctured just above the pubis without wounding the peritoneum.

The **superior** or **abdominal surface** is entirely free, and covered everywhere by the peritoneum, which in the male is prolonged also for a short distance upon the base of the bladder. In the male this surface is often in contact with the sigmoid loop of the colon, and in the female with the uterus, as well as, in both sexes, with convolutions of the small intestine. Beneath the peritoneum, in the male, a part of the vas deferens is found on each side of the hinder portion of this surface.

The **summit** is connected to the anterior abdominal wall by a tapering median cord, named the *urachus*, which is composed of fibrous tissue, mixed at its base with plain muscular fibres, which are prolonged upon it from the bladder. This cord, becoming narrower as it ascends, passes upwards from the apex of the bladder

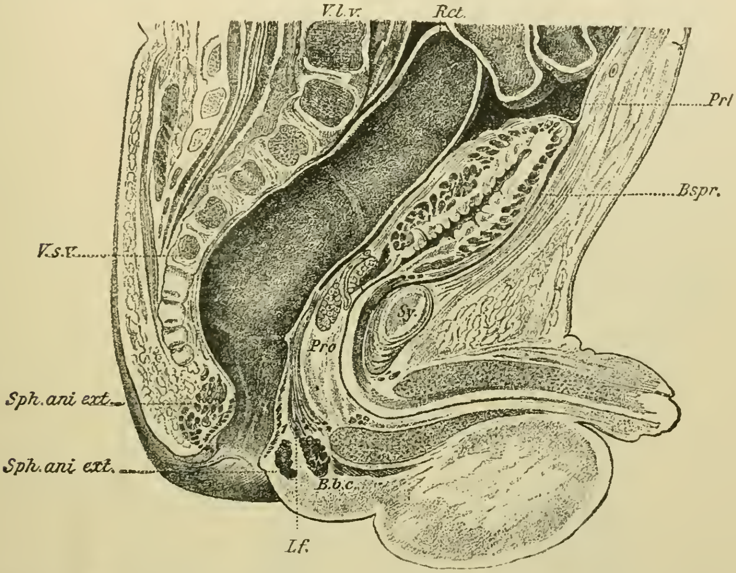


Fig. 230.—Median section of the pelvis of a newly-born male child. (Disse.)

V.l.v, body of 5th lumbar vertebra; *V.s.v*, body of 5th sacral vertebra; *Sy*, pubic symphysis; *Rct*, rectum (distended); *Prt*, peritoneum; *Bspr*, prævesical cleft; *Pro*, placed just below median lobe of prostate; *Lf*, longitudinal muscular fibres of rectum; 1, sphincter ani int.

between the linea alba and the peritoneum, to reach the umbilicus, where it becomes blended with the dense fibrous tissue found in that situation.

The urachus, which forms in the early fœtal state a tubular connection between the urinary bladder and the allantois, preserves, according to Luschka, vestiges of its original condition in the form of a long interrupted cavity, with irregularities and dilatations, lined with epithelium similar to that of the bladder, and sometimes communicating by a fine opening with the vesical cavity.

As during distension the summit of the bladder rises more rapidly than the peritoneum is detached from the anterior abdominal wall, a peritoneal pouch, gradually increasing in depth, is formed between the top of the bladder and the anterior abdominal wall. It is generally estimated that, even in extreme distension, the bladder is seldom uncovered by peritoneum for more than two inches above the pubic symphysis.

The **sides** of the bladder, when this organ is empty, are very narrow, but when it is distended they are rounded and prominent, and are each of them crossed obliquely by the cord of the obliterated hypogastric artery, which is connected posteriorly with the superior vesical artery, and runs forwards and upwards to the umbilicus, approaching the urachus above the summit of the bladder. Behind and

above this cord the side of the bladder is covered with peritoneum, but below and in front of it the peritoneum does not reach the bladder, which is here connected to the sides of the pelvic cavity by loose areolar tissue containing fat, and, near its anterior and lower part, by the broad expansion from the recto-vesical fascia, forming the *lateral true ligament.* The vas deferens crosses obliquely the hinder part of this lateral surface, from before backwards and downwards, and turning over the obliterated hypogastric artery, descends on the inner side of the ureter, to the base of the bladder (fig. 232).

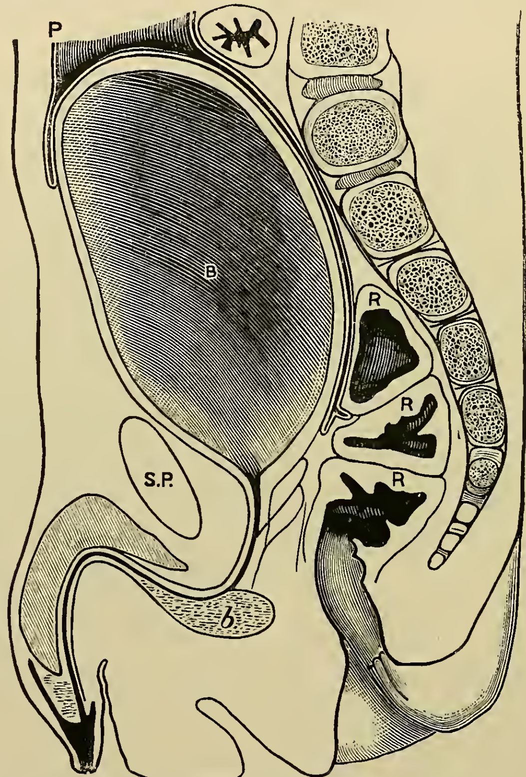


Fig. 231.—Median section of the pelvis of a male child 7 months old. Bladder naturally distended with urine. Natural size. (J. S.)

P, peritoneum ; S. P., pubic symphysis ; B, bladder ; R, rectum ; *b*, bulb of corpus spongiosum. In this specimen the distance from the umbilicus to the top of the pubic symphysis was 7 cm., and the vertical extent of the bladder in contact with the anterior abdominal wall and uncovered by peritoneum was 3 cm.

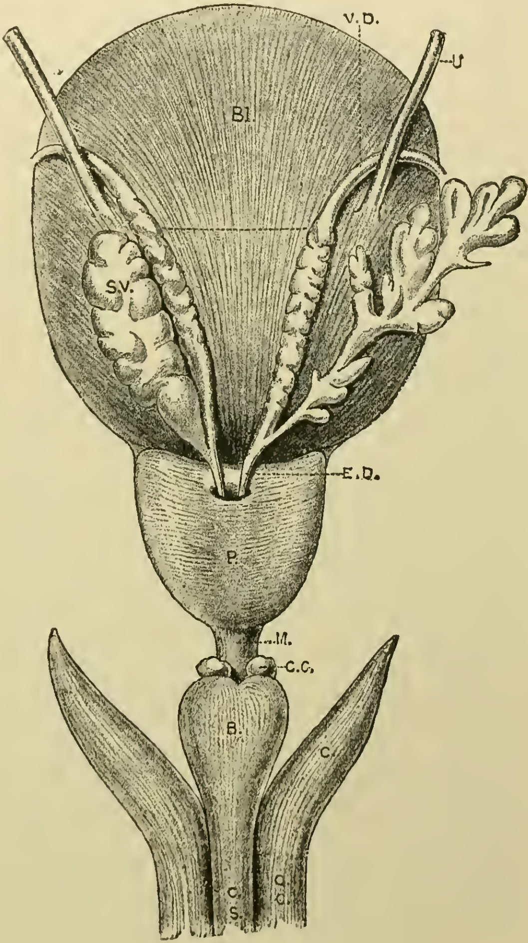
The anterior and lateral surfaces of the bladder, between the anterior and lateral true ligaments of the bladder below and the peritoneum above, are connected with the neighbouring structures by loose areolar tissue, an arrangement which obviously must facilitate the movements of the bladder. The space occupied by this tissue is sometimes termed the *cavum prævesicale*, or *cavum Retzii.*

The **base** or **fundus** (fig. 232) is the widest part of the bladder. It is directed downwards as well as backwards, and differs according to the sex in its relations to other parts. In the *male* it rests against the second portion of the rectum, and is covered superiorly for a short space by the peritoneum, which, however, is immediately reflected from it upon the rectum, so as to form the *recto-vesical pouch* (fig. 227). Below the line of reflection of the serous membrane the base of the

bladder is adherent to the rectum by dense areolar tissue over a triangular area bounded at the sides by the vasa deferentia and vesiculæ seminales (fig. 232), while in front its apex reaches the prostate gland. It is in this triangular space, which, in the natural state of the parts, is by no means so large as it appears after they are disturbed in dissection, and seldom measures more than an inch from base to apex, that the bladder may be punctured from the rectum without injury to the peritoneum. In the *female* the base of the bladder is of less extent, and does not

Fig. 232.—BASE OF THE MALE BLADDER, PROSTATE, &C., IN THE MALE. (J. S.)

Bl, part of base covered by peritoneum, separated by a dotted line from a triangular space left uncovered by that membrane; U, ureter; S. V., seminal vesicle; E. D., ejaculatory duct; P, prostate; M., membranous part of urethra; B, bulb; C. S., corpus spongiosum; C. G., Cowper's gland.



reach so far back in the pelvis as in the male, for it rests against the front of the neck of the uterus and the upper part of the anterior wall of the vagina, both of which organs intervene between it and the rectum. This part of the bladder is connected with the vagina and cervix uteri by loose areolar tissue, and above it there is a shallow utero-vesical pouch of peritoneum. In both sexes the vesical orifice of the urethra is usually the lowest part of the bladder in the erect posture. It is generally situated about an inch behind the middle of the pubic symphysis.

Disse (Merkel u. Bonnet, Anatomische Hefte, i) found that the distance of the orifice from the conjugate of the pelvic inlet in seven adult males varied from 44 mm. to 65 mm., while in women it was placed more deeply in the pelvis, being, on an average, 60 mm. below the pelvic inlet.

Ligaments of the bladder.—The *true ligaments* of the bladder, four in number, two anterior and two lateral, all derived from the recto-vesical portion of the pelvic fascia, are described in Vol. II., Pt. 2.

The *false ligaments*, or peritoneal folds, are described as five in number. Two of them, named *posterior* false ligaments or *recto-vesical folds*, run forwards in the male along the sides of the rectum to the posterior and lateral aspects of the bladder, and bound the sides of the recto-vesical cul-de-sac. In the female these posterior folds pass forwards from the sides of the uterus, and are comparatively small. The two *lateral* false ligaments extend from the iliac fossæ to the sides of the bladder, which they join at the level of the obliterated hypogastric arteries. The *superior* false ligament (*ligamentum suspensorium*) is the portion of peritoneum

which descends from the umbilicus on the urachus and obliterated hypogastric arteries to the summit of the bladder.

Peculiarities in Shape and Position according to Age.—In the newly-born child the bladder is much higher than in the adult. Thus, its urethral orifice is at the level of the upper border of the pubic symphysis, and the anterior surface of the bladder, entirely uncovered by peritoneum, lies against the anterior abdominal wall, opposite about the lower two-thirds of the space between the pubes and the umbilicus (fig. 230). If the bladder be empty, its cavity in a median section shows a long anterior limb passing from the urethral orifice upwards and forwards towards the umbilicus, but there is no indication of a posterior limb such as has already been described in the adult. If the bladder be distended, it usually has an ovoid form, with the large end of the oval directed downwards and backwards. The bladder is commonly described as being at this age an abdominal organ, but, as a rule, only one-half of it lies above the plane of the pelvic inlet. After birth the bladder rapidly descends into the pelvis, and acquires a more rounded form when contracted. In an infant three and a half months old, with the bladder contracted, the peritoneum was reflected from the anterior abdominal wall on to the bladder 10 mm. above the pubic symphysis, the distance from this point to the umbilicus being 48 mm. Again, in a boy, aged five years, in which the bladder was also contracted, the peritoneum passed on to the back of the pubic symphysis before being reflected on to the bladder (Symington). According to Disse, the vesical orifice of the urethra sinks rapidly from birth up to the beginning of the third year, then slowly until the commencement of the ninth year, when it remains stationary until puberty, at which period it again slowly descends until it gains its adult position.

Interior of the bladder.—On opening the bladder, its internal surface is found to be lined by a smooth membrane, which is comparatively loosely attached to the other coats, so that in the empty condition of the organ it is nearly everywhere thrown into small wrinkles or rugæ, which disappear as soon as the bladder is distended. Besides these, the interior of the bladder is often marked by reticular elevations or ridges, corresponding with fasciculi of the muscular coat.

At the lower part of the bladder is seen the orifice leading into the urethra, around which the mucous membrane is corrugated longitudinally. Immediately behind the urethral opening, at the lower part of the fundus, is a smooth triangular surface, having its apex turned forwards, which, owing to the firmer adhesion of the mucous membrane to the subjacent tissue, never presents any rugæ, even when the bladder is empty. This surface is named the *trigone* (*trigonum vesicæ*, Lieutaud) ; at its postero-superior angles are the orifices of the two ureters, situated in a distended bladder about an inch and a half from each other, and nearly the same distance from the antero-inferior angle, where the bladder opens into the urethra. When the bladder is contracted, this area is diminished in size.

The orifices of the ureters, presenting the appearance of oval slits, are directed obliquely forwards and inwards : they are united by a curved elevation, convex in front, which extends generally outwards and backwards beyond them, and which corresponds in position with a muscular band which joins them together and to the neck of the bladder. Proceeding forwards from opposite the middle of this is another slight elevation of the mucous surface, named the *uvula vesicæ*, which extends to the posterior margin of the urethral orifice. In the female the trigone is small and the uvula indistinct. In the male the uvula lies a little in advance of the middle lobe of the prostate, and is sometimes prolonged on the posterior wall of the prostatic portion of the urethra as far as the verumontanum. It is produced by a thickening of the submucous tissue. In its natural state this may contribute to the more perfect closure of the orifice of the bladder.

STRUCTURE OF THE BLADDER.

The bladder is composed of a *serous*, a *muscular*, a *submucous*, and a *mucous* coat, and supplied with numerous blood-vessels and nerves.

The **serous** or **peritoneal coat** is a partial covering, investing only the posterior and upper half of the bladder, and reflected from it upon the surrounding parts in the manner already described in detail.

The **muscular coat** consists of unstriped muscular fibres, which are described as forming layers, the outer of which consists of bundles of fibres more or less longitudinal, and the next of fibres more circular in disposition ; while beneath this is another imperfect longitudinal layer.

The *external longitudinal fibres* (fig. 233, A, B, C) are most distinctly marked on the anterior and posterior surfaces of the bladder. Commencing in front at the neck of the organ, from the pubes in both sexes (*musculi pubo-vesicales*), and, in the male, from the adjoining part of the prostate gland, they may be traced upwards along the anterior surface to the summit of the bladder ; and they may likewise be followed down over the posterior surface and base to the under part of the neck of the bladder, where they become attached to the prostate in the male, and to the front of the vagina in the female. Upon the sides the superficial fasciculi run more or less obliquely, and often intersect one another ; in the male they reach the prostate. At the summit a few are continued along the urachus. The longitudinal fibres taken together constitute what has been named the *detrusor urinæ* muscle, but, according to Griffiths, these fibres "do not form a separate muscle, and have not a separate function."

The so-called *circular* fibres form a thin and somewhat irregular reticulated layer distributed over the body of the bladder, having various appearances in different bladders. Their course may in general be looked upon as transverse, but for the most part throughout the upper two-thirds of the bladder they cross one another in very oblique bands : towards the lower part of the organ they assume a more circular course, and upon the fundus and trigone form a tolerably regular layer. Close to and around the urethral orifice, in immediate connection with the prostate in the male, they are often described as forming a thick band of circular fibres, which has been named the *sphincter vesicæ*. According to Griffiths, there is, however, no thickening of the muscular fibres in this situation to justify the term of sphincter.

The *third stratum* of fibres, still more deeply situated, and which might be termed internal longitudinal, was first described by Ellis, who distinguished it as "submucous." It is thin, and its bundles have a reticular arrangement, but with a general longitudinal direction. At the trigone the inner bands of muscular fibres are united together and to the mucous membrane by dense areolar tissue, while they are separated from the external longitudinal fibres by a thin layer of loose areolar tissue.

The muscular coat of the bladder forms so irregular a covering that, when the organ is much distended, intervals arise in which the walls are very thin ; and, should the internal or mucous lining protrude in any spot through the muscular bundles, a sort of hernia is produced, which may go on increasing, so as to form what is called a vesical sacculus, or *appendix vesicæ*, the bladder thus affected being termed *sacculated*. Hypertrophy of the muscular fasciculi, which is liable to occur in stricture of the urethra or other affections impeding the issue of the urine, gives rise to that condition named the *fasciculated* bladder, in which the interior of the organ is marked by strong reticulated ridges or columns, with intervening depressions.

Next to the muscular coat, between it and the mucous membrane, but much more intimately connected with the latter, is a well-marked layer of areolar tissue,

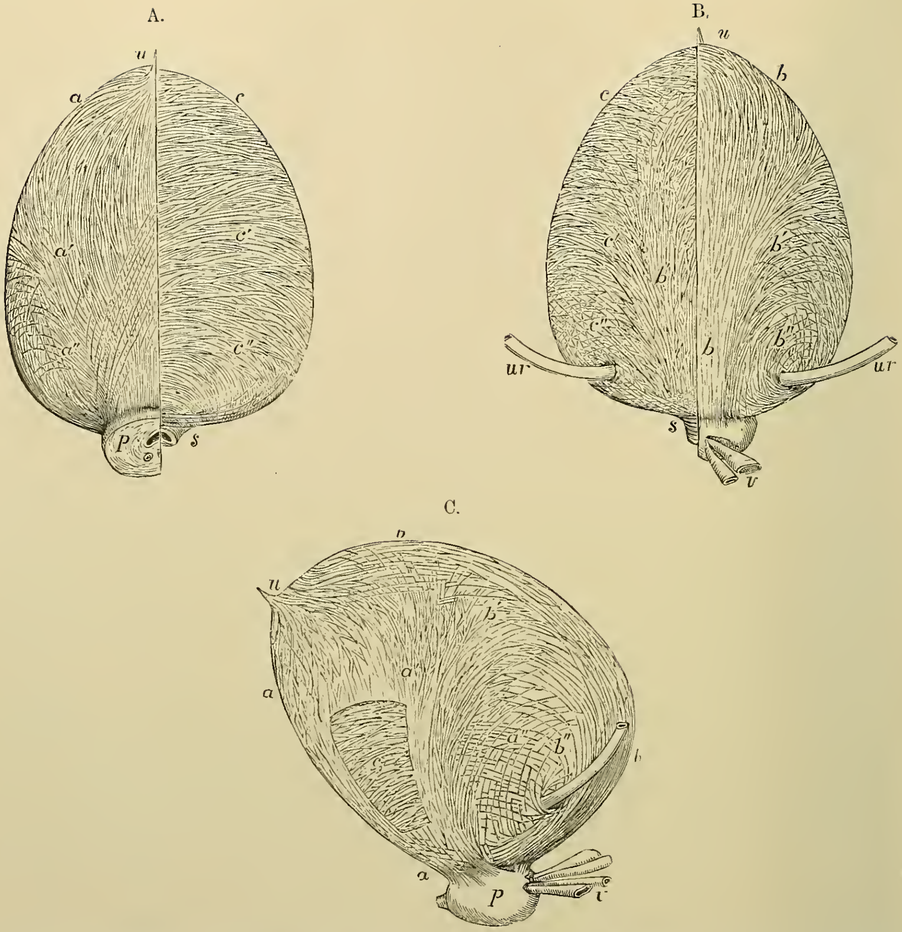


Fig. 233.—Dissections showing the course of the muscular fibres of the bladder (Allen Thomson, after Pettigrew, and from nature). $\frac{1}{3}$.

A. From the front.

On the right side the superficial fibres are shown ; on the left the deep or circular fibres chiefly are displayed. *a*, on the right side, the median and most superficial bands of the longitudinal fibres, in which a slight decussation of fibres is seen : a', those diverging somewhat ; a'', the lowest, which pass much more obliquely ; the attachment of the longitudinal fibres to the prostate is shown ; on the left side, *c*, the upper, c', the middle, c'', the lowest set of circular or deeper fibres ; at *s*, the thickest and most transverse sets of these fibres forming the sphincter ; *p*, right half of the prostate, the left half having been removed ; *u*, the urachus, into which some of the longitudinal fibres are seen prolonged.

B. From the back.

On the right side the superficial fibres are displayed ; on the left the deeper fibres of the same kind or intermediate fibres, and some of the circular fibres ; *b*, *b*, the median, most superficial and strongest bands of longitudinal fibres on the right side ; b', the more diverging set of fibres near the middle of the bladder ; b'', the most divergent fibres which surround the entrance of the ureters ; on the left side, *c*, c', and c'', indicate the deeper circular fibres passing round at various levels, and crossing with the deeper diverging fibres posteriorly ; *s*, the most transverse fibres at the neck forming the sphincter ; *u*, the urachus ; *ur*, the ureters ; the left half of the prostate has been removed to show the sphincter ; *v*, part of the right vas deferens and vesicula seminalis.

C. From the left side.

The anterior and posterior superficial fibres are seen running from below upwards, crossing each other by their divergence on the side of the bladder, and are indicated by the same letters as in the preceding figures ; at *c*, a portion of the anterior longitudinal fibres has been removed so as to expose the deeper circular fibres.

the vascular or **submucous coat.** This submucous areolar layer contains a large number of fine coiled fibres of elastic tissue.

The **mucous membrane** of the bladder is soft, smooth, and of a pale rose colour. It is continuous above with the lining membrane of the ureters and kidneys, and below with that of the urethra. Neither here nor in the ureters is the mucous membrane provided with a muscularis mucosæ. It adheres loosely to the muscular tissue, and is thus liable to be thrown into wrinkles, except at the trigone, where it is always more even. It is covered with a (transitional) stratified epithelium (fig. 234), similar to that of the ureters. The cells vary much in form according to the condition of distension of the bladder, for in the distended organ they are flattened out so as to cover a larger surface, while in the empty condition of the bladder they are of less diameter and proportionately higher. Many of the superficial cells contain two nuclei. The deeper cells divide by karyokinesis, and the newly formed cells take the place of others which are thrust towards the surface. There are no definite glands in the bladder, but in some places there are solid down-growths

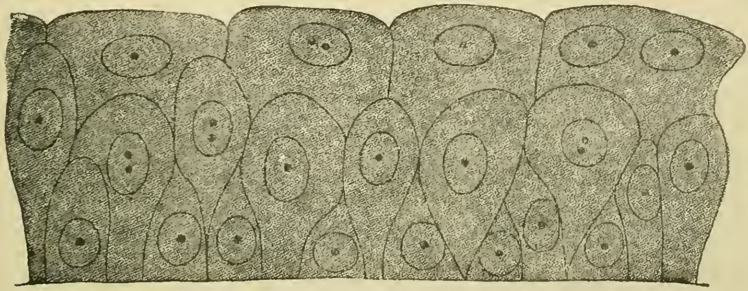


Fig. 234.—Epithelium of the urinary bladder.

a, superficial: *b*, intermediate; and *c*, deep layer of cells, partly double.

of the deeper epithelium cells into the mucous membrane, which have sometimes been described as true glands.

Vessels and nerves.—Arteries.—The *superior vesical* arteries proceed from the remaining pervious portions of the hypogastric arteries; in the adult they appear as direct branches of the internal iliac. The *inferior vesical* arteries are usually derived from the anterior division of the internal iliac. In the female the *uterine* arteries also send branches to the bladder. The neck and base of the organ appear to be the most vascular portions. The **veins** form large plexuses around the neck, sides, and base of the bladder; they eventually pass into the internal iliac veins. The **lymphatics** follow a similar course. **Nerves.**—The nervous supply of the bladder is bilateral, each half having its own nerves. On each side the nerves are derived from two sources, viz. :—(*a*) from the *third*, the *fourth*, and sometimes the *second sacral nerves*: these fibres, which are known as the pelvic splanchnics (Gaskell), consist almost entirely of fine medullated nerves, and pass from the sacral spinal nerves directly to the pelvic plexus without going through the gangliated cord of the sympathetic: (*b*) from the *hypogastric plexus of the sympathetic*: these fibres are nearly all non-medullated. They arise from the upper lumbar nerves, and reach the hypogastric plexus through the aortic plexus and the inferior mesenteric ganglion. Both sets unite in the pelvic plexus, which contains numerous ganglia, and the fibres which go from the plexus to the bladder are mainly, if not entirely, non-medullated. According to v. Zeissl, the pelvic splanchnics supply only the longitudinal fibres of the bladder, but Griffiths found that stimulation of the peripheral cut ends of these nerves produced contraction of the entire muscular coat on the same side. These

nerves also contain sensory fibres from the bladder. Stimulation of the peripheral cut ends of the hypogastric fibres causes feeble contraction of the corresponding half of the bladder (Langley), and if the bladder be previously contracted it causes rapid relaxation (Griffiths). The hypogastric plexus also contains sensory fibres, which probably reach the spinal cord through the *twelfth dorsal* and *first and second lumbar nerves.*

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REPRODUCTIVE ORGANS.

By E. A. SCHÄFER and J. SYMINGTON.

I. IN THE MALE SEX.

Under this head are included—1, the testes with their ducts and coverings; and, 2, the urethra, with certain accessory parts, such as the prostate and Cowper's glands. The urethra in the male is at once the outlet for the urine from the bladder and the products of secretion from the sexual glands. Extending from the neck of the bladder to the extremity of the penis, it is surrounded in its first part by the prostate gland, and there receives the excretory ducts of the testes and vesiculæ seminales; its second part passes through the triangular ligament of the perineum; and its third and longest part passes along the perineum and penis, surrounded by the corpus spongiosum.

THE TESTES AND THEIR ACCESSORY STRUCTURES.

The *testes* or *testicles*, the two glandular organs which produce the spermatozoa, are situated in the pouch of integument termed the *scrotum*, each being suspended by its own *spermatic cord.*

The spermatic cord.—The parts which form this cord are the excretory duct of the testis, named the vas deferens, the spermatic artery and veins, lymphatics, nerves, and connecting areolar tissue. Besides this last the cord has several coverings in common with the testis. The structures mentioned come together to form the cord at the internal or deep abdominal ring, and, extending through the abdominal wall obliquely downwards and towards the middle line, escape at the superficial or external abdominal ring, whence the cord descends over the front of the pubis into the scrotum.

The inguinal canal.—By the term inguinal canal is understood the space occupied by the spermatic cord as it passes through the abdominal wall. It extends from the deep to the superficial abdominal ring, and is about an inch and a half in length. In the upper part of this course the cord has the fascia transversalis behind it, and is covered in front by the lower fibres of the internal oblique and transversalis muscles; lower down it lies in front of the conjoined tendon of these muscles, the fibres of which have arched inwards over it, and its cremasteric covering is in contact anteriorly with the aponeurosis of the external oblique muscle. The inguinal canal is therefore said to be bounded posteriorly by the fascia transversalis above and the conjoined tendon below, and anteriorly by fibres of the transversalis and internal oblique muscles above, and the aponeurosis of the external oblique muscle below; while its floor is formed by the curving backwards of Poupart's ligament, and its roof by the apposition of the layers of the abdominal wall and the arched fibres of the internal oblique and transversalis muscles.

As it enters the inguinal canal, the cord receives a covering from the infundibuliform fascia, a thin layer continuous with the fascia transversalis, and prolonged down from the margin of the deep abdominal ring; within the canal it receives a covering from the cremaster muscle and its layer of fascia; and as it emerges from the canal there is added superficially to this, the intercolumnar fascia prolonged from the margin of the superficial abdominal ring.

The scrotum.—The scrotum forms a purse-like investment for the testes and part of the spermatic cords. Its condition is liable to some variation according to the state of the health and other circumstances ; thus it is short and corrugated in robust persons and under the effects of cold, but becomes loose and pendulous in persons of weak constitution, and under the relaxing influence of heat. A superficial division into two lateral halves is marked by a slight median ridge, named the *raphe,* extending forwards to the under side of the penis, and backwards along the perineum to the margin of the anus.

The coverings of the cord and testis in the scrotum may be enumerated from without inwards as follows, viz., the *skin,* and the *dartos tissue,* the *intercolumnar fascia,* the *cremaster muscle* and *fascia,* and the *infundibuliform fascia,* which is united to the cord by a layer of loose areolar tissue ; lastly, the special serous membrane of the testis named the *tunica vaginalis,* which forms a close sac, of which one part lines the scrotum and the other closely envelopes the testis.

1. The **skin** of the scrotum is very thin, and is of a darker colour than that of the body generally ; it is commonly thrown into rugæ or folds, which are more or less distinct according to the circumstances already mentioned. It is furnished with sebaceous follicles, the secretion from which has a peculiar odour, and it is covered over with thinly scattered curled and flattened hairs, the bulbs of which may be seen or felt through the skin when the scrotum is stretched. The superficial blood-vessels are also readily distinguished through this thin integument.

2. Immediately beneath the skin of the scrotum there is found a thin layer of a peculiar loose reddish-brown tissue, endowed with contractility, and named the **dartos tunic.** This subcutaneous layer is continuous with the superficial fascia of the groin, perineum, and inner side of the thighs, but assumes a different structure, and is entirely free from fat. The dartoid tissue, which is more abundant on the fore part of the scrotum than behind, forms two distinct sacs, for the corresponding testes, united together along the middle line so as to establish a median partition named the *septum scroti,* which is adherent below to the deep surface of the raphe, and reaches upwards to the root of the penis. The dartos is very vascular, and owes its contractile properties to the presence of a considerable amount of unstriped muscular tissue (Kölliker).

3. The **intercolumnar** or **spermatic fascia,** a very thin and transparent but relatively firm layer derived from the tendon of the external oblique muscle of the abdomen, is attached above to the margins of the external ring, and is prolonged downwards upon the cord and testis. It lies at first beneath the superficial fascia, and lower down beneath the dartos, and it is intimately connected with the layer next mentioned.

4. The **cremasteric layer** is composed of scattered bundles of striped muscular fibres, connected together into a continuous covering by intermediate areolar membrane. The red muscular portion, which is continuous with the lower border of the internal oblique muscle of the abdomen, constitutes the *cremaster muscle,* and the entire covering is named the *cremasteric fascia.* By the action of the cremaster the cord is shortened and the testicle is raised towards the abdomen.

5. The **infundibuliform fascia,** continuous above with the *fascia transversalis* and situated immediately beneath the cremasteric fascia, invests the cord completely, and is connected below with the posterior part of the testicle and the outer surface of its serous tunic. On forcing air beneath the infundibuliform fascia, a quantity of loose and delicate areolar tissue is seen to connect its deep surface with the vas deferens and spermatic blood-vessels, and to form lamellæ between them. This areolar tissue is continuous above with the subserous areolar tissue found beneath the peritoneum on the anterior wall of the abdomen ; below, it is lost upon the back

of the testicle. Together with the infundibuliform fascia, it forms the *fascia propria* of Astley Cooper.

Lying amongst this loose areolar tissue, in front of the upper end of the cord, there is often seen a fibrous band, which is connected above with the pouch of peritoneum found opposite the upper end of the inguinal canal, and which passes downwards for a variable distance along the spermatic cord. Occasionally it may be followed as a fine cord, as far as the upper end of the tunica vaginalis; sometimes no trace of it can be detected. It is the vestige of a tubular process of the peritoneum, which in the fœtus connects the tunica vaginalis with the general peritoneal membrane. The testicle is placed within the abdomen during the greater part of fœtal life; but at a period considerably prior to its escape from the abdominal cavity, a pouch of peritoneum already extends down into the scrotum. Into this pouch, or *processus vaginalis peritonæi*, the testicle projects from behind, supported by a duplicature of the serous membrane, named the *mesorchium*. Sooner or later after the gland has descended into the scrotum, the upper part or neck of this pouch becomes contracted and finally obliterated, from the internal abdominal ring down nearly to the testicle, leaving no trace but the indistinct fibrous cord already described, while the lower part remains as a closed serous sac surrounding the testicle, and which is thence named the tunica vaginalis.

In the female fœtus an analogous pouch of peritoneum descends for a short distance along the round ligament of the uterus, and has received the appellation of the *canal of Nuck*. Of this traces may almost always be seen in the adult.

The neck of the processus vaginalis sometimes becomes closed at intervals only, leaving a series of sacculi along the front of the cord; or a long pouch may continue open at the upper end, leading from the abdominal cavity into the inguinal canal. In other instances, the peritoneal process remains altogether pervious, and the cavity of the tunica vaginalis is thus made continuous with that of the peritoneum. In such a case of congenital defect, a portion of intestine or omentum may descend from the abdomen into the inguinal canal and scrotum, and constitute what is named a congenital hernia. Lastly, one or both testes may remain permanently within the abdomen, or their descent may be delayed till after puberty, when it may occasion serious disturbance. Retention of the testes in the abdomen (cryptorchismus) is, in many instances, the accompaniment of arrested development of the glandular structure; it is, however, a peculiarity which may be present without impotence.

In a few mammals, as the elephant, the testes remain permanently within the abdomen; in a much larger number, as the rodentia, they only descend at each period of rut. The complete closure of the tunica vaginalis is peculiar to man, and may be considered as connected with his adaptation to the erect posture.

6. The **tunica vaginalis.**—This tunic forms a shut sac, of which the opposite free surfaces are in contact with each other. Like the serous membranes in general, of which it presents one of the simplest forms, it may be described as consisting of a *visceral* and a *parietal* portion. The visceral portion, *tunica vaginalis testis*, closely invests the greater part of the body of the testis, as well as the epididymis, between which parts it is depressed in the form of a pouch (*digital fossa*), and lines their contiguous surfaces, and it adheres intimately to the proper fibrous tunic of the gland. Along the posterior border of the gland, where the vessels and ducts enter or pass out, the serous coat, having been reflected, is wanting. This portion of the serous covering frequently presents villous prolongations on the borders of the epididymis and upper end of the testis; these processes, sometimes of considerable length, are covered in some places with cylindrical, in others with layers of flat epithelium.

The parietal or scrotal portion of the tunica vaginalis is more extensive than that which covers the body of the testis; it reaches upwards, sometimes for a considerable distance, upon the spermatic cord, extending somewhat higher on the inner than on the outer side. It also reaches downwards below the testicle, which, therefore, appears to be suspended at the back of the serous sac, when this latter is distended with fluid; a fold, or so-called ligament, being left projecting at the lower end of the epididymis (fig. 235, *f*).

Vessels and nerves of the scrotum and spermatic cord.—The **arteries** are derived from several sources. The two *external pudic* arteries, branches of the femoral, reach the front and sides of the scrotum, supplying the integument and

dartos ; the *superficial perineal* branch of the internal pudic artery is distributed to the back part of the scrotum ; and, lastly, more deeply seated than either of these is a branch given from the epigastric artery, named *cremasteric*, which is chiefly distributed to the cremaster muscle, but also supplies small branches to the other coverings of the cord, and by its ultimate divisions anastomoses with the other vessels. The *artery of the vas deferens*, a long slender vessel derived from the superior or inferior vesical, accompanies the tube in its whole length. The **veins** accompany the arteries. The veins of the cord form the spermatic or pampiniform plexus elsewhere described. The **lymphatics** of the scrotum pass into the inguinal lymphatic glands.

The **nerves** also proceed from various sources. The *ilio-inguinal*, a branch of the lumbar plexus issuing by the external abdominal ring, supplies the integuments of the scrotum ; this nerve is joined also by a filament from the *ilio-hypogastric* branch of the same plexus : sometimes two separate cutaneous nerves come forward through the external ring. The two *superficial perineal* branches of the pudic nerve accompany the artery of the same name and supply the inferior and posterior parts of the scrotum. The *inferior pudendal*, a branch of the small sciatic nerve, joins with the perineal nerves, and with them is distributed to the sides and lower part of the scrotum. Lastly, the *genital branch of the genito-crural* nerve, reaching the spermatic cord at the internal abdominal ring, passes with it through the inguinal canal, and supplies the fibres of the cremaster muscle, besides sending a few filaments to the other deep coverings of the cord and testicle.

THE TESTICLES.

The **testicles**, the principal reproductive glands (δίδυμος, ὄρχις), are suspended obliquely in the scrotum by means of the cord and membranes already described ;

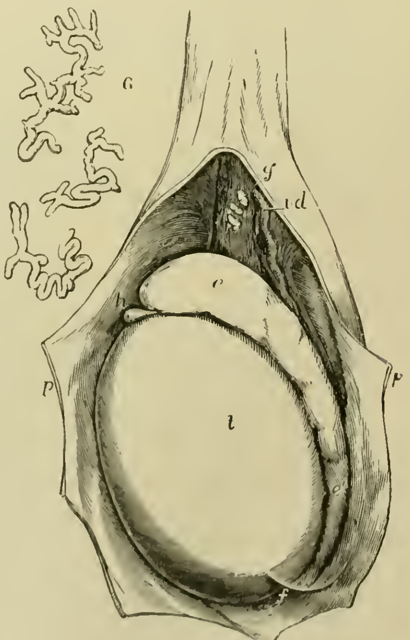


Fig. 235.—The left tunica vaginalis opened, showing the testis, epididymis, &c., from the outer side (Allen Thomson.)

p, *p*, cut edges of the parietal layer of the tunica vaginalis drawn aside ; *t*, body of the testis ; *e*, *e'*, epididymis ; *f*, a fold of the tunica vaginalis passing from the body of the testis to the side. In the upper part of the figure the tunica vaginalis has been dissected off at the place of its reflection on the cord to show *v d*, the vas deferens, and *g*, the organ of Giraldès ; G, the three small nodules of this organ enlarged about ten times, and showing the remains of tubular structure within them ; *h*, hydatid of Morgagni, or appendix of the testicle.

they are usually placed at unequal heights, that of the left side being lower than the other. They are of an ovoid form, but are slightly compressed laterally, so that they have two somewhat flattened sides or faces, an upper and a lower end, an anterior and a posterior border. They are about an inch and a half (37 mm.) long, an inch and a quarter (28 mm.) wide from back to front, and nearly an inch (24 mm.) thick from side to side. The weight of each varies from three-quarters of an ounce to an ounce (15 to 24·5 grammes, W. Krause).

The front and sides of the testis, together with the upper and the lower ends, are free, smooth, and closely invested by the tunica vaginalis. The posterior border is attached to the spermatic cord, and it is

here that the vessels and nerves enter or pass out. When the testis is suspended in its usual position, its upper end is directed obliquely forwards and outwards, as well as upwards, whilst the lower, which is rather smaller, has the opposite direction. It follows from this that the posterior or attached border is turned upwards and inwards, and the outer flattened face slightly backwards.

Attached to the posterior border of the gland, and resting also on the neighbouring portion of its outer face, is a long narrow body, the *epididymis*, which forms part of the excretory apparatus of the testicle, and is principally composed of the convolutions of a long tortuous canal or efferent duct, to be presently described. Its upper extremity, larger than the lower, projects forwards on the upper end of the testis, and is named the *head* or *globus major* (fig. 235, *e*) ; the lower, which is more pointed, is termed the *tail* or *globus minor* (*e'*) ; whilst the intervening portion is named the *body*. The convex surface of the epididymis and the thin anterior border are free, and covered by the tunica vaginalis. The concave surface, or that directed towards the testis, is also free, except at the upper and lower ends, and invested by the same tunic, which here forms a pouch between the epididymis and the outer face of the testicle, and nearly surrounds the epididymis, except along its posterior border, which is united to the gland by a duplicature of the serous membrane, containing numerous blood-vessels. At its upper and lower extremity, the epididymis is attached to the testis by fibrous tissue and a reflection of the tunica vaginalis, the globus major also by the efferent ducts of the testis.

At the back of the testis and epididymis, beneath the fascia propria, opposite the lower two-thirds of the testis, is a considerable amount of unstriped muscular tissue, the *inner muscular tunic* of Kölliker.

On the front of the globus major, somewhat to the outer side, there are usually found one or more small pedunculated bodies covered by an extension of the tunica vaginalis and formed mainly by connective tissue and blood-vessels. These are the *hydatids of Morgagni*. They are commonly regarded as remains of part of the fœtal structure termed Müller's duct. One of them, of a more regularly pyriform shape, and more constant than the rest, lies closely between the head of the epididymis and the testis.

This has been thought, but as it would appear on insufficient evidence, to be the homologue of the ovary in the male sex (Fleischl, Krause). Its surface is ciliated, and a canal lined by ciliated epithelium and opening into the cavity of the tunica vaginalis is sometimes contained within it.

STRUCTURE OF THE TESTIS.

The testis is enclosed in a strong capsule, the **tunica albuginea**. This is a dense unyielding fibrous membrane, of a white colour, and of considerable thickness, which immediately invests the soft substance of the testis, and preserves the form of the gland. It is composed of bundles of fibrous tissue, which interlace in every direction. The outer surface is covered by the tunica vaginalis, except along the posterior border of the testis, where the spermatic vessels pass through and the two extremities of the epididymis are attached.

In the interior, the fibrous tissue of the tunica albuginea is prolonged from the posterior border for a short distance into the substance of the gland, so as to form within it an incomplete vertical septum, known as the *corpus Highmori*, and named by Astley Cooper *mediastinum testis*. It extends from the upper nearly to the lower end of the gland, and it is wider above than below. The firm tissue of which it is composed is traversed by a network of seminal ducts, and by the larger blood-vessels of the gland, which are lodged in channels formed in the fibrous tissue.

From the front and sides of the corpus Highmori numerous slender fibrous

cords and imperfect septa of connective tissue are given off in radiating directions, and are attached by their outer ends to the internal surface of the tunica albuginea

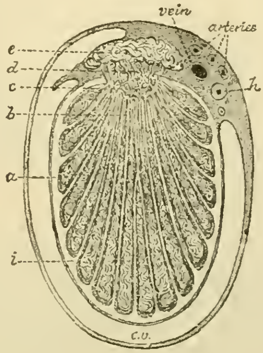


Fig. 236.—Transverse section through the right testicle and the tunica vaginalis. (Modified from Kölliker.)

a, seminiferous tubes, converging at *b*, to the mediastinum; *c*, rete testis; *d*, vasa efferentia; *e*, epididymis; *h*, section of vas deferens; *i*, tunica albuginea, sending septa into the body of the testis; *c.v.*, cavity of tunica vaginalis.

at different points, thus incompletely dividing the glandular substance into lobules. According to Kölliker, plain muscular fibres are prolonged upon these septula. The whole internal surface of the tunica albuginea is covered by a multitude of

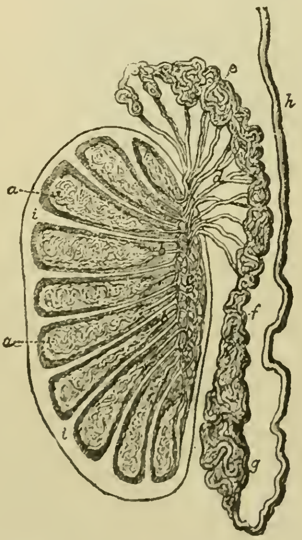


Fig. 237.—Plan of a vertical section of the testicle, showing the arrangement of the ducts.

The true length and diameter of the ducts have been disregarded in this as well as in the preceding figure. *a*, *a*, tubuli seminiferi coiled up in the separate lobes; *b*, vasa recta; *c*, rete vasculosum; *d*, vasa efferentia ending in the coni vasculosi; *e*, *f*, *g*, convoluted canal of the epididymis; *h*, vas deferens; *i*, *i*, section of the back part of the tunica albuginea with fibrous processes running between the lobes.

fine blood-vessels, which are branches of the spermatic artery and veins, and are held together by a delicate areolar web. Similar delicate ramifications of vessels

are seen on the various fibrous offsets of the mediastinum, upon which the blood-vessels are thus supported in the interior of the gland. This vascular network, together with its connecting areolar tissue, constitutes the *tunica vasculosa* of Astley Cooper.

Seminiferous tubules. — The glandular substance of the testis which is included in the fibrous framework formed by the albuginea, the mediastinum, and the trabeculæ, is a mass of convoluted tubules known as the **tubuli seminiferi,** which are somewhat loosely connected together by areolar tissue into the lobes or lobules above mentioned. Of these lobes there are some 100 to 200 (Krause) or more; they are of unequal size, the middle ones being the larger, and are imperfectly

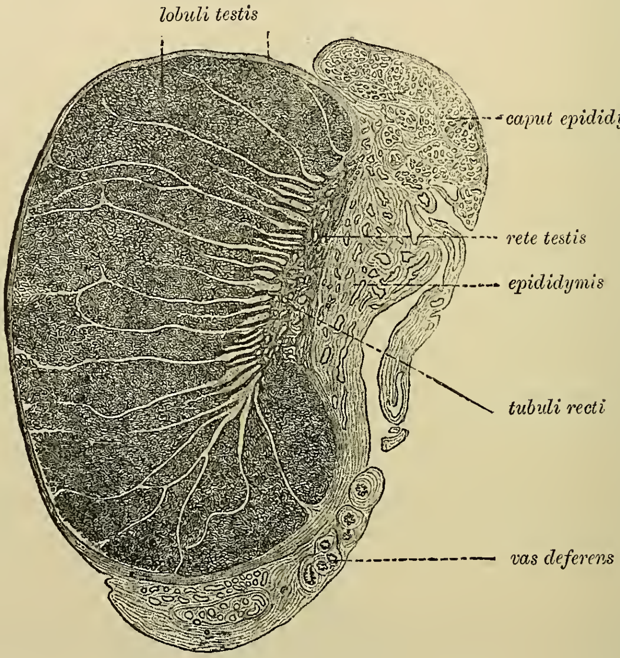


Fig. 238.—Section through the testis and epididymis. (Böhm and v. Davidoff.)

separated from one another, the septa being incomplete. In each lobe are two, three, or more seminiferous tubules closely convoluted, and here and there branched, especially at their anterior or distal extremity, where, in a *cortical zone* near the albuginea, they are stated to communicate frequently laterally with one another. It is not difficult to unravel the tubules for some distance, for their walls are moderately strong, and their diameter (0·2 mm.) large compared with those of other tubular glands, such as the kidney. Their length is estimated to be on an average rather greater than two feet (60 cm.) and their number between 800 and 900 (Lauth). They have a smooth contour, but this is interrupted at intervals by small bulgings, which are more numerous near the commencement of a tubule than near its termination. The walls of the seminiferous tubules are composed of several layers of flattened cells. Of these only the innermost layer is complete, being formed of epithelioid cells closely united edge to edge into a basement membrane. This is strengthened by the other layers, which, however, exhibit intervals between the flattened cells which compose them, these intervals becoming very marked in the outermost layers. In consequence of their being thus formed of several layers, the walls of the tubules have a concentrically striated appearance in cross-section.

The tubules are occupied by an epithelium which consists of several irregular layers of cells, amongst which the *seminal filaments* or *spermatozoa* may be observed in different stages of development (fig. 239). In different tubules of the same testis and even in parts of the same tubule the condition of development of the spermatozoa may be very various, and the epithelium presents corresponding differences both in the number of its layers and the appearance of the cells.

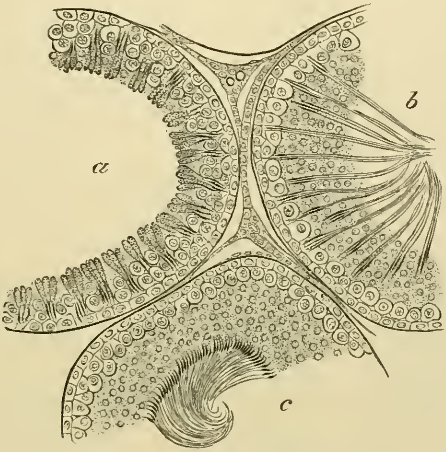


Fig. 239.—SECTION OF PARTS OF THREE SEMINIFEROUS TUBULES OF THE RAT. (E. A. S., from a preparation by Mr. A. Fraser.) Magnified.

a, with the spermatozoa least advanced in development ; *b*, more advanced ; *c*, containing fully developed spermatozoa. Between the tubules are seen strands of interstitial cells with blood-vessels and lymph-spaces.

Structure of the spermatozoa.—A spermatozoon is a minute filiform particle about 0·055 mm. long, consisting of three parts : a *nucleus* or *head*, a *middle piece* or *body*, and a spontaneously vibratile *tail*. In man the **head** is of a flattened oval

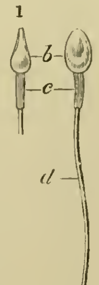


Fig. 240.—HUMAN SPERMATOZOA (Retzius).

1, in profile, the tail not represented ; 2, viewed on the flat ; *b*, head ; *c*, middle-piece ; *d*, tail ; *e*. end-piece of the tail.

shape, appearing pointed when seen in profile and with a depression on each flattened surface. A minute barb-like projection has been described at its extremity (Dowdeswell) ; this is however much more apparent in some animals. The head stains intensely with nuclear dyes, and is mainly formed of chromatin (nuclein). It is about 0·0045 mm. long, 0·0025 mm. broad, and 0·0015 mm. thick. In certain animals it is invested with a clear mantle termed the *head-cap* (Schweigger-Seidel), but this is not easily apparent in man in the completed stage. The head also varies greatly in other respects in different animals, its shape and size being characteristic for each species.

The **middle piece** or **body** of the spermatozoon is nearly cylindrical in man. It is about 0·006 mm. long and less than 0·001 mm. in diameter. It is difficult to make out any structure in it in man, but in some animals (mouse, rat), a spiral thread can be seen closely coiled around its periphery, whilst through its centre a filament passes which appears to be a prolongation of a central filament within the tail and which ends close under the base of the nucleus or head in a globular enlargement known as the *terminal globule* or *globuloid body*.

The **tail** is about 0·045 mm. long, and finer than the middle piece. It tapers towards the extremity. Near its termination it becomes abruptly finer and its terminal sixth (*end-piece* of Retzius) is an extremely delicate fibre, which under certain circumstances can be seen to be composed of three or more of the finest possible fibrils. This end-piece is apparently a direct combination of the central filament of the tail, which is elsewhere invested by a sheath, but is here bare. The distinction between sheath and central filament cannot be made out in the human spermatozoon. In some animals (newt) an undulating membrane with a fine fibre running along its free margin is attached spirally by one border along the whole length of the tail (Leydig): a similar membrane has been described in man (Gibbes, W. Krause, v. Bardeleben). The motion of the spermatozoon is a forward one produced by a spirally lashing movement of the tail, similar to the movements

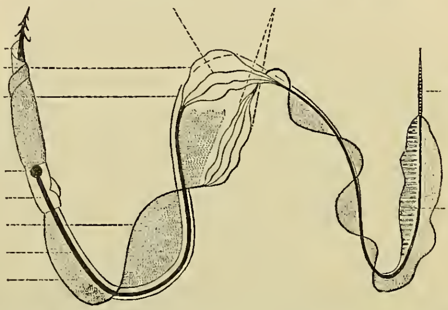


Fig. 241.—Diagram of a Spermatozoon. (Böhm and v. Davidoff.) All the parts here shown have not been made out in the human spermatozoon.

of the cilia of zoospores of bacilli. It may last under favourable conditions for several days after discharge (4 to 9 days, Piersoll).

Several varieties of human spermatozoa have been described, differing from one another chiefly in size. Some are occasionally found which are very much larger than usual (·075 mm. long and ·0035 mm. broad). According to the observations of K. v. Bardeleben (Verhandl. d. Anat. Gesellsch., 1891), founded partly on his own preparations, partly on those of E. M. Nelson, the head of the human spermatozoon consists of several portions, viz., spear, head-cap, and a main part divided into anterior and posterior portions. The *spear*, the existence of which appears to be rather doubtful, is described as an immeasurably fine process unsymmetrically placed, which may be twice as long as the head. Its tip is recurved and hooklike. At its base is an elongated particle staining more deeply than the rest. The *head-cap* is clear and very delicate. The *anterior part of the head* is clear, the *posterior part* cross striated. A protoplasmic fringe extends from the anterior part to the body of the spermatozoon. Within the head is a clear refractive particle (*globuloid*), not staining with ordinary dyes. A short *neck* unites the head to the *body* or *middle piece* of the spermatozoon. Both this and the *tail* (except the end-piece of Retzius) have a frilled membrane along one side: the tail has a special membrane on the opposite side. The tail contains a central filament which extends through the body and head and may be traced even into the spear.

Structure of the epithelium of the seminiferous tubules.—Of the cells forming the epithelium of the seminiferous tubules, there are, in most tubules, three several kinds, differing in situation, in size, and in structure. Those of the first kind, which are termed the *outer* or *lining cells* (*spermatogonia*) form the outermost zone. They are cubical or somewhat flattened cells disposed in a single regular layer next to the basement membrane of the tubule. In some tubules one of these cells may here and there be seen to be elongated and to project between the cells of the next zone, where it comes into connection with a group of developing spermatozoa. Indications of karyokinetic division are also met with in the cells of this layer in certain tubules (fig. 242, 6). In the early fœtal condition the

spermatogonia are the only cells found in the tubule. The cells of the next zone become formed from them by karyokinetic division.

The cells of the second kind, *intermediate* or *spermatogenic cells* (*spermatocysts* of some authors), form a middle or intermediate zone in the tubules. They are large clear cells with conspicuous nuclei, the latter invariably exhibiting some stage of karyokinesis. They lie one, two or more deep, varying in different tubules according to the condition of development of the spermatozoa, and the thickness of the layer they form varies accordingly. When two or more deep, the groups of developing spermatozoa and the elongated spermatogonia with which the groups are connected penetrate between them and tend somewhat to break the continuity of the layer.

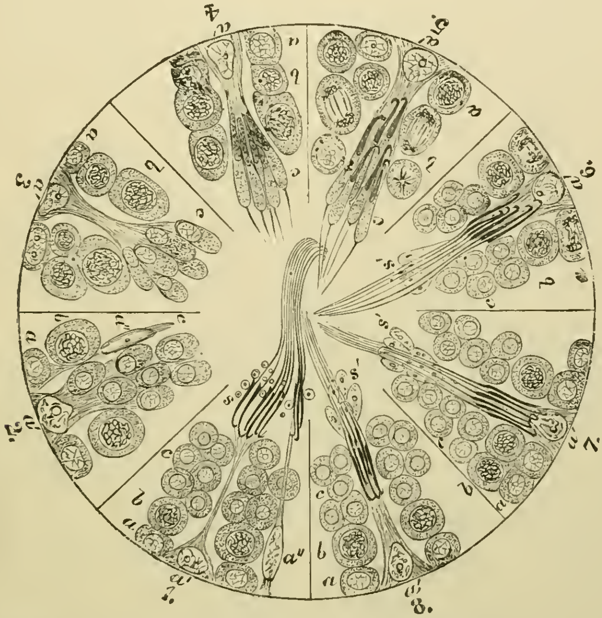


Fig. 242.—Diagram exhibiting the cycle of phases of spermatogenesis in the rat. (E. A. S.)
(This diagram is chiefly founded upon the drawings of H. H. Brown.)

a, lining epithelium cells, seen dividing in 6 ; *a'*, sustentacular cells ; *b*, spermatogenic or mother-cells, with skein-like nuclear filaments : these cells are seen actively dividing in 5 ; *c*, spermatoblasts, forming an irregular column or clump in 6, 7, 8, and 1, and connected to sustentacular cell, *a'*, in 2, 3, 4, and 5. In 6, 7, and 8 advanced spermatozoa of one crop are seen between columns of spermatoblasts of the next crop. *s'*, parts of the spermatoblasts which disappear when the spermatozoa are fully formed ; *s*, seminal granules, probably resulting from the disintegration of *s'* ; *a''*, in 1 and 2. are nuclei of sustentacular cells, which are probably becoming extruded.

These spermatogenic cells, which are originally derived from the spermatogonia, themselves give origin by two or more stages of karyokinetic division to the cells of the next layer or spermatoblasts, but some of the cells resulting from the first division are not converted into spermatoblasts. These remain as a layer of spermatogenic cells, ready in due time to produce by further division the next crop of spermatoblasts.[1]

The third kind of cell in the seminiferous tubule is the spermatoblast. The *spermatoblasts* (*spermatids* of some authors) are derived as just stated from division of the spermatogens or spermatocysts, and on the other hand are directly trans-

[1] According to Brown all the spermatogenic cells or spermatocysts are converted, after division, into spermatoblasts, and fresh spermatocysts are produced for the next crop of spermatoblasts by division of some of the lining cells or spermatogonia.

formed into spermatozoa: hence they were termed by H. H. Brown, *young spermatozoa.* They form in most tubules an innermost zone of small closely packed granular-looking and ill-defined cells, which appear blended into a continuous mass (fig. 239, *c*); they are, however, not so blended, but are quite discontinuous. Their nuclei are small and do not stain deeply with reagents : they show no signs of proliferation. In some tubules these cells are already becoming elongated (fig. 239, *a*), and in the various tubules of the same testis every stage of transformation is met with between them and the fully developed spermatozoa. As this transformation proceeds they are seen to collect into definite groups (fig. 239, *b*) which penetrate between the cells of the intermediate layer, and become connected with and imbedded in cells of the outer layer (*sustentacular cells*) which elongate to receive them (fig. 242). These sustentacular cells in all probability subserve a nutritive function for the developing spermatozoa. When the development is approaching completion the group of spermatozoa moves again towards the middle of the tubule, the connection with the outer layer becoming gradually longer and more attenuated until finally the heads of the fully developed spermatozoa form a complete zone next to the lumen of the tubule, into which their tails project, being bent sharply round and extending for a short distance along the course of the tubule (fig. 239, *c* ; 242, 1, *a*).

While this gradual transformation of spermatoblasts into spermatozoa is going on in a tubule, a fresh crop of spermatoblasts is being formed in the same tubule to take the place of those thus transformed. This crop is formed as before by proliferation of the spermatogenic cells which have remained next to the lining layer,[1] and hence it happens that in the same tubule at least two phases of development of spermatozoa or of spermatoblasts are constantly to be seen. But after the completion of one crop of spermatozoa, the spermatoblasts, which are to become transformed into the next crop, remain quiescent until the first crop has been discharged. The spermatogenic cells divide at first each into two, and thus form a first generation. This division takes place by what is termed by Flemming the "heterotypical form" of karyokinesis, the split chromosomes long remaining connected at their ends, and the stage of metakinesis being greatly prolonged. During the dyaster phase a second longitudinal splitting occurs, and the daughter-nuclei again divide immediately, without entering into a resting condition, and without a further splitting of the chromosomes, to form the nuclei of the cells of the third generation. The cells of this third generation have, therefore, only half the typical number of chromosomes in their nuclei, and these are the cells which become transformed into spermatoblasts. In the final division, therefore, it appears that the number of chromosomes, or chromatic segments of the nucleus, becomes, by failure of the usual longitudinal cleavage, reduced to one half the number usual in the cells of the particular species of animal under observation. The resulting nuclei, therefore, of the spermatoblasts resemble, in this respect, the nucleus of the ovum after extrusion of the second polar globule, and it is only on the conjunction of the two within the fertilized ovum that the typical number of chromosomes is re-established.

The process of reduction of chromosomes in the final division of the spermatic cells was first shown by O. Hertwig to occur in Ascaris, and it has since been established for the salamander (by Flemming) and some other animals. It has been thought to be of general occurrence, but this cannot as yet be regarded as conclusively proved, especially in mammals, in which the observation of the number and changes of the chromosomes is extremely difficult.

Transformation of the spermatoblasts into spermatozoa.—The fully formed spermatoblasts, or spermatids, are small, granular cells, with round nuclei.

[1] Or which have been formed by a new karyokinetic division of the spermatogonia (see note on previous page).

In developing into spermatozoa, these become elongated. The nucleus alters in shape and passes towards one end of the cell, where it forms the head of the spermatozoon. Within the protoplasm a filament begins to form, soon growing out beyond the rest of the cell as the tail. The protoplasm of the cell partly remains to form the body or middle piece ; partly becomes detached and disintegrated, as the maturation of the spermatozoon is completed.

Changes in the nucleus.—The nucleus of the spermatoblast is at first spherical.

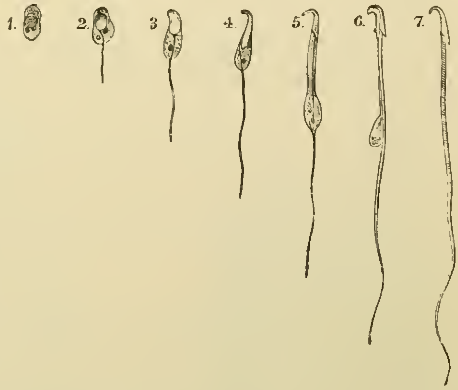


Fig. 243. PHASES OF TRANSFORMATION OF A SPERMATOBLAST OR SPERMATID INTO A SPERATOZOON IN THE RAT. (H. H. Brown.)

with a somewhat faint outline. It shows the usual network of a resting nucleus, but has comparatively little tendency to stain with dyes (poor in chromatin). As development proceeds it becomes at first oval, then conical, then greatly elongated and compressed, so that no structure can be seen within it. In the meantime its chromatin becomes increased, and finally forms a dense mass, which gradually takes on the shape and position of the head of the future spermatozoon.

Changes in the protoplasm. —Within the body of the cell but near the nucleus various structures can be made out (Moore), viz. the *archoplasm,* a clear or nearly clear portion of the protoplasm (which may contain a vacuole),

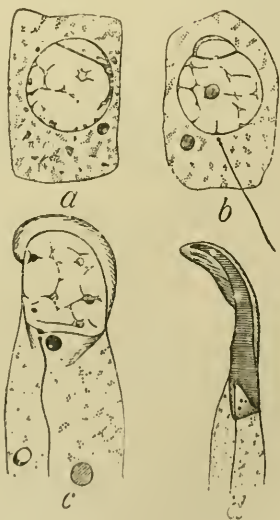


Fig. 244.—FOUR STAGES IN THE DEVELOPMENT OF SPERMATOBLASTS OR SPERMATIDS INTO SPERMATOZOA (Lenhossék).

The tail filament is seen to be connected with the (double) centrosome of the spermatid.

the so-called *chromatic body*, a small mass of darkly staining material close to the nucleus and probably a detached portion of its chromoplasm, and the *centrosome*, which is usually double (fig. 244, *a, b*). As the nucleus passes towards the inner end of the cell, with its pointed end projecting beyond the general circumference, and the base directed towards the centre of the cell, the body of the cell becomes elongated, assuming first an oval and then a pear shape, with the nucleus embedded in the smaller end of the pear. In connection with the centrosome, a thread—*axial filament* — begins to appear in the protoplasm, and is soon seen to emerge from the opposite or larger end of the pear-shaped cell, the protoplasm of which is probably continued over it.

This filament is the rudiment of the "tail," and gradually elongates. It is not clear how the head-cap is formed, but probably from nucleoplasm, this being perhaps itself covered by clear protoplasm. The spermatozoon is now developed, but the middle piece is still large and pyriform, and its peripheral portion forms a projection which partly encircles the tail (fig. 243). The projection in question disappears in the further course of development, being partly absorbed into the rest of the middle piece and into the tail, partly becoming detached and disintegrated. It contains some deeply staining granules, which are found mingled with the spermatozoa when these are set free (*spermatic granules*).

Interstitial tissue of the testicle.—The tissue which connects the seminiferous tubules is in some respects peculiar. It consists of fine fasciculi and laminæ of areolar tissue, these being covered by and partly composed of flattened epithelioid cells. Between the laminæ and fasciculi are large cleft-like spaces, containing lymph, and almost everywhere enclosing the basement membrane of the tubules. If these spaces are injected by the puncture-method, the injecting fluid flows away by the lymphatics of the spermatic cord. It is found to penetrate between the incomplete outer layers of the membrane of the tubules, but is arrested by the innermost layer.

The blood-vessels are conducted at first along the trabeculæ, and from these they pass into the angular interstices between the tubules. Here they are supported by the areolar tissue, and accompanied and often completely surrounded by tracts of peculiar epithelium-like polyhedral cells somewhat like the cortical cells of the suprarenal capsules, and, like these, often containing yellowish granules. They are known as the *interstitial cells* of the testis, and have been regarded as specially modified connective tissue cells (plasma-cells, Waldeyer), or as epithelial cells derived from the Wolffian body (Klein), but until their development has been fully traced, nothing certain with regard to their nature can be stated. In sections of the fœtal testis, the cells in question are not distinguishable from the other cells of the developing intertubular connective tissue. Similar cells are met with in the stroma of the ovary.

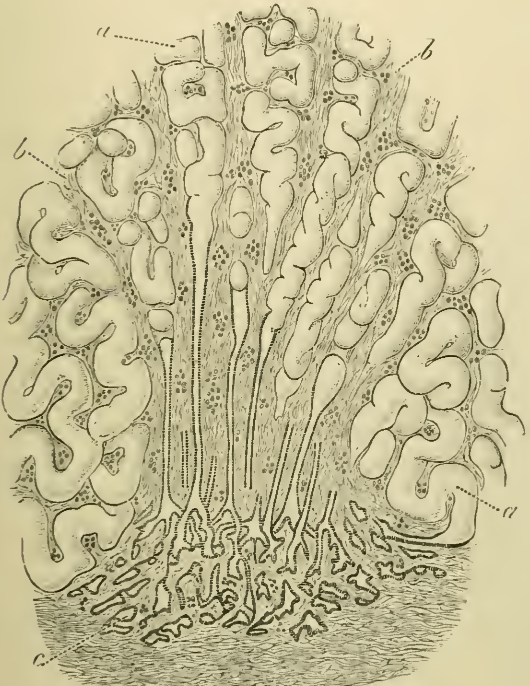
The capillaries form a close network over the walls of the seminiferous tubules.

The nerves of the testis appear not to be provided with ganglia, as is the case with most of the visceral nerves, nor have they been traced into the interior of the seminiferous tubules, but they ramify over the tubules and many are distributed to the blood-vessels.

Ducts of the testis.—As the convoluted tubuli seminiferi approach the mediastinum testis they unite, as before said, with one another at acute angles into a smaller number of tubes which have a less flexuous course, and at length become nearly straight. Close to the mediastinum they taper into short, straight tubes (**tubuli recti**), of smaller diameter than the seminiferous tubes, and differing from them in the character of their epithelium (fig. 245). This, in the straight tubules, is a single layer of flattened or cubical cells continuous with the outer or lining cells of the seminiferous tubes. The basement membrane is also continued on to the straight tubules.

The straight tubules open into a network of vessels which lies in the fore part of the mediastinum, and was named by Haller, **rete vasculosum testis** (fig. 245, *c*). The tubes composing the rete have no proper walls, but are merely channels in the fibrous stroma, lined by flattened epithelium. Their diameter is greater than that of the tubuli recti. The secretion from the testis is accumulated in the rete testis, and is conducted to the upper and back part of the testis, whence it is conveyed away by the efferent tubules, or **vasa efferentia.** These are from twelve to fifteen, or

sometimes twenty in number; they perforate the tunica albuginea beneath the globus major of the epididymis, of which they may be said to form a part, and in the convoluted canal of which they ultimately terminate. On emerging from the testis, these vasa efferentia are straight, but, becoming more convoluted as they proceed towards the epididymis, they form a series of small conical masses, the bases of which are turned in the same direction, and which are named *coni vasculosi*



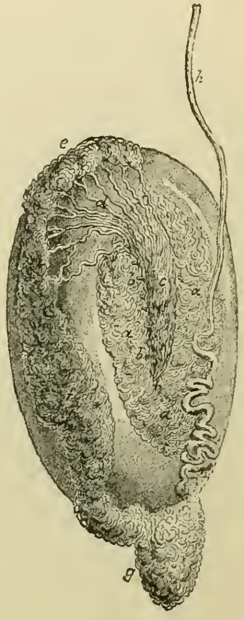


Fig. 245.—Passage of convoluted seminiferous tubules into straight tubules, and of these into the rete testis. (Mihalkovics.)

a, seminiferous tubules; *b*, fibrous stroma continued from the mediastinum testis; *c*, rete testis.

Fig. 246.—Ducts of the testicle injected with mercury. (From Haller.)

a, body of the testicle; *b*, tubuli in the interior of the gland; *c*, rete vasculosum; *d*, vasa efferentia terminating in the coni vasculosi; *e*, *f*, *g*, convoluted canal of the epididymis; *h*, vas deferens ascending from the globus minor of the epididymis.

(figs. 237, 246). They are about 0·5 mm. in diameter. The largest of the cones is about 14 mm. long, and when unrolled, each is found to consist of a single coiled duct, varying from 150 mm. to 200 mm. in length, and the diameter of which gradually decreases from the testis to the epididymis (Huschke). Opposite the globus major these separate efferent vessels open, at intervals which, in the unravelled tube, are found to be about 75 mm. in length, into a single canal or duct, the intervening and subsequent convolutions of which constitute the epididymis itself.

The **canal of the epididymis** (fig. 246, *e*, *f*, *g*) is disposed in very numerous coils, and extends from the globus major downwards to the globus minor or tail, where, turning upwards, it is continued on as the *vas deferens*. When its complicated flexuosities are unrolled, it is found to be twenty feet (6 or more metres) in length. The smallest windings are supported and held together by fine areolar

tissue; but, besides this, numerous incomplete, transverse, fibrous partitions are interposed between larger masses of the coils, which have been named the *lobes* of the epididymis. The canal of the epididymis is, at its commencement, about 0·4 mm. in diameter, but diminishing as it proceeds towards the globus minor, it is about 0·27 mm., after which it again increases in size, and becomes less deeply convoluted as it approaches the vas deferens. Its coats, which are at first thin, become thicker in its progress.

The vasa efferentia have a layer of circular muscular fibres, to which in the tube of the epididymis is added an external longitudinal layer, both being relatively thin.

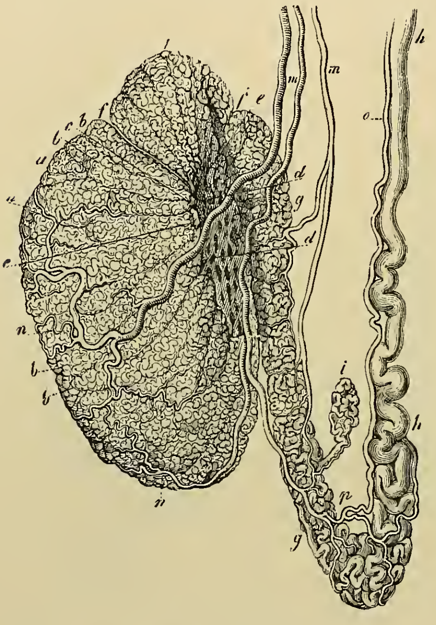


Fig. 247.—Injected testis, epididymis, and vas deferens. (From Kölliker, after Arnold.) $\frac{2}{1}$.

a, body of the testicle; *b*, lobules; *c*, vasa recta; *d*, rete vasculosum; *e*, vasa efferentia; *f*, coni vasculosi; *g*, epididymis; *h*, vas deferens; *i*, vas aberrans; *m*, branches of the spermatic artery passing to the testicle and epididymis; *n*, ramification in the testis; *o*, artery of the vas deferens; *p*, its union with a twig of the spermatic artery.

The epithelial lining cells are columnar in form, and are ciliated, the cilia being long, and causing by their movement a current towards the vas deferens. In the epididymis the cells are greatly elongated, in the vasa efferentia they are shorter; in the lower part of the epididymis the cilia disappear. Between the fixed ends of the columnar cells other smaller cells are met with.

The **vas deferens** (fig. 247, *h*), or excretory duct of the testis, forms the continuation upwards of the convoluted canal of the epididymis. It commences at the lower end of the epididymis, and, at first rather tortuous but afterwards becoming straight, it ascends upon the inner side of the epididymis, and along the back of the testicle, separated from both, however, by the blood-vessels passing to and from the gland. Continuing then to ascend in the spermatic cord, the vas deferens accompanies the spermatic artery, veins and nerves, as far as the internal abdominal ring. Between the testicle and the external ring its course is nearly vertical: it lies behind the spermatic vessels, and is readily distinguished by its hard cord-like feel. It then passes obliquely upwards and outwards along the inguinal canal, and reaching the inner border of the internal abdominal ring, it leaves the spermatic vessels (which extend to the lumbar region), and turns suddenly downwards and inwards into the pelvis, crossing over the external iliac vessels, and turning round the outer or iliac side of the epigastric artery. Running beneath the peritoneum, it reaches the side of the bladder (fig. 249), upon which it descends, curving backwards and downwards to the hinder surface of that viscus, and finally passes forwards to the base of the prostate gland. In its course within the pelvis, it crosses over the cord of the obliterated hypogastric artery, and lies to the inner side of the ureter. Beyond this point, where it ceases to be covered by the peritoneum, it is attached to the coats of the bladder, in contact with the rectum, and gradually approaching its fellow of the opposite side. Upon the base of the bladder, the vasa deferentia are situated between two elongated receptacles, named the seminal vesicles (fig. 249, S.V.); and, close to the base of the prostate, each vas deferens ends by joining with the

duct from the corresponding seminal vesicle on its outer side to form one of the common seminal or ejaculatory ducts (fig. 249, E.D.).

The vas deferens measures about a foot in length (300 mm.); but when extended and unravelled, about half as much again, or even more than this. In the greater part of its extent it is cylindrical or slightly compressed, and has an average diameter of about 2·5 mm., with a lumen of 0·7 mm.; but towards its termination, beneath the bladder, it becomes enlarged and sacculated, forming the *ampulla* of Henle, and resembling in shape and structure a part of the seminal vesicle.

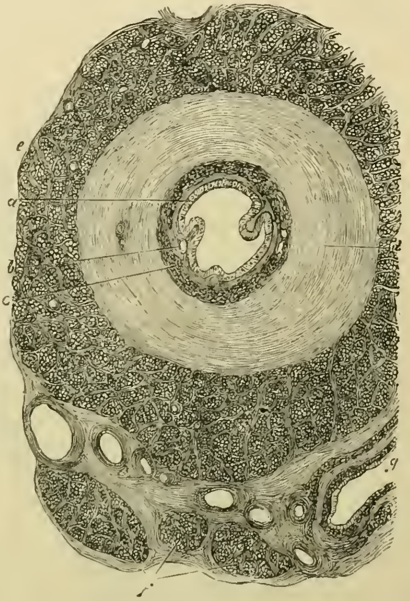


Fig. 248.—Section across the commencement of the vas deferens. (Klein.)

a, epithelium; *b*, mucous membrane; *c*, *d*, *e*, inner, middle, and outer layers of the muscular coat; *f*, bundles of the internal cremaster muscles; *g*, section of a blood-vessel.

Previously to its junction with the duct of that vesicle, it again becomes narrowed into a smaller and straight cylindrical canal. The walls of the vas deferens are very dense and strong, and feel hard to the touch, owing to the large proportion their thickness bears to the inner cavity of the tube. In the sacculated portion the passage is much wider, and the walls are thinner in proportion. Small simple and branched tubular glands beset the mucous membrane of this portion of the duct (Henle).

Besides an external areolar investment, and an internal mucous membrane, the vas deferens is provided with an intermediate thick muscular tunic, of a deep yellowish colour. This coat consists of two layers of plain fibres, an outer of longitudinal and an inner of circular fibres (fig. 248, *d*, *e*). In addition, near the commencement of the tube is an internal longitudinal stratum, extremely thin, and constituting not more than $\frac{1}{5}$th of the muscular coat (fig. 248, *c*); in the ampulla, the inner longitudinal fibres are absent.

The lining membrane exhibits on its surface three or four longitudinal ridges, and, besides this, in the sacculated portion of the duct, it is marked by numerous finer rugæ which enclose irregular polyhedral spaces, resembling in this alveolar character the lining membrane of the seminal vesicles. The epithelium is of the columnar kind, and not ciliated. As in the epididymis, there is a deeper layer of small cells between the columnar cells.

According to Steiner the epithelium may be ciliated in parts, or it may show a character similar to that of the ureter and bladder.

Vas aberrans.—This name was applied by Haller to a long narrow tube, or diverticulum (fig. 247, *i*), discovered by him, and almost invariably met with, which leads off from the lower part of the canal of the epididymis, or from the commencement of the vas deferens, and, becoming tortuous and convoluted, is rolled up into an elongated mass which extends upwards for an inch or more amongst the vessels of the spermatic cord, where the tube ends by a closed extremity. Its length, when it is unravelled, ranges from about two to twelve or fourteen inches; and its width increases towards its blind extremity. Sometimes this diverticulum is branched, and occasionally there are two or more such aberrant ducts. Its structure appears to be similar to that of the vas deferens. Its origin is probably connected with the Wolffian duct of the fœtus, but the exact mode of its formation and its office are unknown. Luschka states that occasionally it does not communicate with the canal of the epididymis, but appears to be a simple serous cyst.

Roth has described other small blind vasa aberrantia lying along the epididymis and connected with the rete testis.

Organ of Giraldès.—The small body thus named is situated in the front of the cord immediately above the caput epididymis (see fig. 235, *g*). It consists usually of several small irregular masses containing convoluted tubules lined with columnar ciliated epithelium, and is scarcely to be recognised until the surrounding connective tissue has been rendered transparent by re-agents. It has also received the name of *paradidymis* (Waldeyer). Its tubules appear to be vestiges of part of the Wolffian body.

The **seminal vesicles** are two membranous receptacles, situated, one on each side, upon the base of the bladder, between it and the rectum. When distended, they form two long sacculated bodies, somewhat flattened on the side next the bladder, to

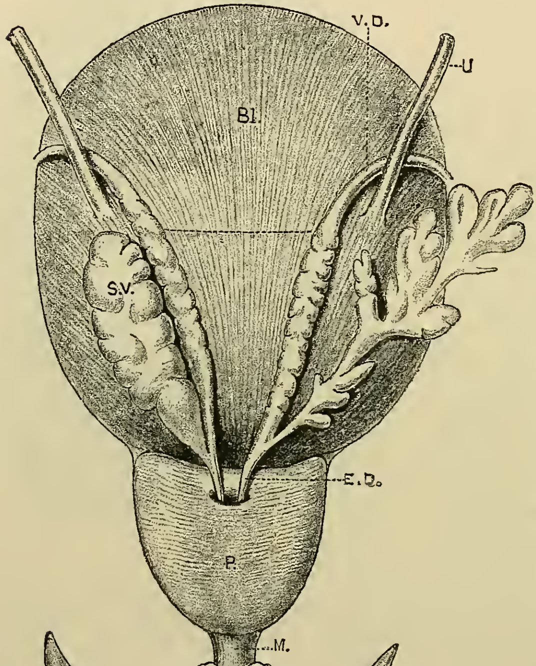


Fig. 249.—Base of the male bladder, the prostate gland, the root of the penis, &c. (J. S.)

Bl, part of base covered by peritoneum, separated by a dotted line from a triangular space left uncovered by that membrane ; u, ureter ; s. v., seminal vesicle ; e. d., ejaculatory duct ; p, prostate ; m., membranous part of urethra ; b, bulb ; c. s., corpus spongiosum ; c. g., Cowper's gland.

which they are firmly attached, and convex on their posterior surface ; they are widened above and narrow below (fig. 249, s. v.). Their length is usually about two inches (50 mm.), and the greatest breadth about half an inch (12·5 mm.); but they vary both in size and shape in different individuals, and also on the two sides.

Their upper obtuse extremities are separated widely from each other, but anteriorly they converge so as to approach the two vasa deferentia, which run forwards to the prostate between them. With the vasa deferentia thus interposed, they occupy the two diverging sides of the triangular portion of the base of the bladder, which lies upon the rectum, and is bounded behind by the line of reflexion of the peritoneum at the extremity of the recto-vesical pouch. The seminal vesicles themselves also rest upon the rectum, but are separated from it by a layer of the recto-vesical fascia, which attaches them to the base of the bladder.

The sacculated appearance of the seminal vesicles is owing to their peculiar formation. Each consists of a tube somewhat coiled and repeatedly doubled on itself, and invested by dense fibrous tissue. When unrolled, this tube is found to be from four to six inches long, and about the width of a quill. Its upper extremity is closed, so that it forms a long cul-de-sac ; but there are generally, if

not always, several longer or shorter branches or diverticula connected with it, which also end by closed extremities (fig. 249). Inferiorly the seminal vesicle becomes straight and narrowed, and ends opposite the base of the prostate by uniting on its inner side, at an acute angle, with the narrow termination of the corresponding vas deferens to form a single canal, which is the common seminal or ejaculatory duct.

The vesiculæ seminales receive branches from the *inferior vesical* and *middle hæmorrhoidal* arteries and veins. The nerves belong to the sympathetic system, and come from the hypogastric plexus.

In structure, the seminal vesicles resemble very closely the adjoining sacculated portions of the vasa deferentia. Besides an external investment, connected with the recto-vesical fascia, and containing vessels of considerable size, lymphatics, and gangliated nervous cords, they have a muscular coat and a mucous membrane. The muscular layers are thin compared with those of the vas deferens, and consist of two layers, an outer of longitudinal, and an inner of circular fibres. A considerable amount of plain muscular tissue is found covering the posterior surface and extending transversely between the two vesicles. There are also longitudinal fibres traceable over the vesicles from those of the bladder (Ellis, Henle). The mucous membrane is traversed by very many fine rugæ, which form an alveolar structure resembling that seen in the gall-bladder, but deeper and enclosing much finer meshes. The epithelium of the vesicles is columnar with a deeper layer of small polyhedral cells.

The ducts of the testis serve as receptacles or reservoirs for the semen, as is proved by a microscopic examination of their contents ; but, this is not usually the case with the seminal vesicles : it is probable that they secrete a peculiar fluid which is incorporated with the semen.

The **common seminal** or **ejaculatory ducts,** two in number (fig. 249, E.D.), are formed on each side by the junction of the narrowed extremities of the corresponding vas deferens and vesicula seminalis, close to the base of the prostate gland. From this point they run forwards and downwards, at the same time approaching each other, and then pass side by side through the prostate between its middle and two lateral lobes. After a course of nearly an inch, during which they become gradually narrower, they end in the floor of the prostatic portion of the urethra by two small slit-like orifices placed on the verumontanum, one on each prominent margin of the opening of the prostatic utricle (fig. 261, *d*). For a short distance the ejaculatory ducts run in the substance of the walls of the utricle.

The coats of the common seminal duct, as compared with those of the vas deferens and vesicula, are very thin. The muscular coat consists of an outer thin circular and an inner longitudinal layer, the outer longitudinal fibres blending with the muscular tissue of the prostate. The strong areolar tunic almost entirely disappears after the entrance of the ducts between the lobes of the prostate, but muscular fibres may be traced into the prostatic portion. The mucous membrane becomes gradually smoother as it passes into that of the urethra. Its epithelium is like that in the seminal vesicles and vas deferens. According to Henle, the muscular fibres of the duct as it passes through the prostate are separated from one another by blood-vessels, and form the trabeculæ of a layer of cavernous tissue.

These ejaculatory ducts convey the fluid contained in the seminal vesicles and vasa deferentia into the urethra. Their canal gradually narrows as they approach their termination, where the diameter is reduced to 0·5 mm.

Vessels and nerves of the testis.—The testicle and its excretory apparatus receive blood-vessels and nerves from sources which are different from those giving the vascular and nervous supply to the coverings of those parts.

Arteries.—The *spermatic artery*, or proper artery of the testicle, is a slender and remarkably long branch, which arises from the abdominal aorta, and passing down

the posterior abdominal wall reaches the spermatic cord, and descends along it to the gland. In early fœtal life its course is much shorter, as the testis is then situated near the part of the aorta from which the artery arises. As the vessel approaches the testicle, it gives off small branches to the epididymis, and then divides into others which perforate the tunica albuginea at the back of the gland, and pass through the corpus Highmori; some spread out on the internal surface of the tunica albuginea, whilst others run between the lobes of the testis, supported by the fibrous processes of the mediastinum. The smallest branches ramify on the delicate membranous septa between the lobes, before supplying the seminiferous tubes.

The vas deferens receives from one of the vesical arteries a long slender branch which accompanies the duct, and hence is named the *artery of the vas deferens.* It ramifies in the coats of the duct, and reaches as far as the testis, where it anastomoses with the spermatic artery.

Veins.—The *spermatic veins* commence in the testis and epididymis, passing out at the posterior border, where they unite into larger vessels, which freely communicate with each other as they ascend along the cord, and form the *pampiniform plexus.* Ultimately two or three veins follow the course of the spermatic artery into the abdomen, where they unite into a single trunk (*spermatic vein*), that of the right side opening into the inferior vena cava, and that of the left into the left renal vein.

Lymphatics.—The lymphatics accompany the spermatic vessels and terminate in the lumbar lymphatic glands, which encircle the large blood-vessels in front of the vertebral column. As previously stated, they begin from intercommunicating lymph spaces which occupy the intervals between the tubuli seminiferi.

Nerves.—The nerves are derived from the sympathetic system. The *spermatic plexus* is a very delicate set of nervous filaments, which descend upon the spermatic artery from the renal and aortic plexuses. Some additional filaments, which are very minute, come from the hypogastric plexus, and accompany the artery of the vas deferens.

THE PENIS.

The penis is composed principally of erectile tissue, arranged in three long somewhat cylindrical masses, which are enclosed in fibrous sheaths, and are united together so as to form a three-sided prism which receives a covering from the general integument. Of these masses, two, named *corpora cavernosa penis*, placed side by side, form the principal part of the organ, whilst the other, situated beneath the two preceding, surrounds the canal of the urethra, and is named *corpus cavernosum urethræ* or *corpus spongiosum.*

The penis is attached at its root to the symphysis of the pubes, and to the pubic arch; in front it ends in an enlargement named the *glans*, which is structurally similar to and continuous with the corpus spongiosum. The intermediate portion or *body* of the penis, owing to the manner in which its three component parts are united together, has three somewhat flattened and grooved sides and three rounded borders: the upper side is named the *dorsum.* The *glans penis*, which is slightly compressed above and below, has at its extremity a vertical fissure forming the external orifice of the urethra (*meatus urinarius*); its base, which is wider than the body of the penis, is hollowed out to receive the narrowing extremities of the corpora cavernosa; its border is rounded and projecting, and is named the *corona glandis*, behind which is a constriction of the penis named the *cervix.* The median fold of integument connecting the glans below the urethral orifice to the inferior border of the penis is named the *frænum of the prepuce.*

The integument of the penis, which is continued from that of the pubes and scrotum, forms a simple investment as far as the neck of the glans. Here it is doubled up in a loose fold, the *prepuce* or *fore-skin.* The inner layer of this fold

is firmly attached behind the cervix; and from thence the integument, becoming closely adherent, is continued forwards over the corona and glans, as far as the orifice of the urethra, where it meets with the mucous membrane of the urethra.

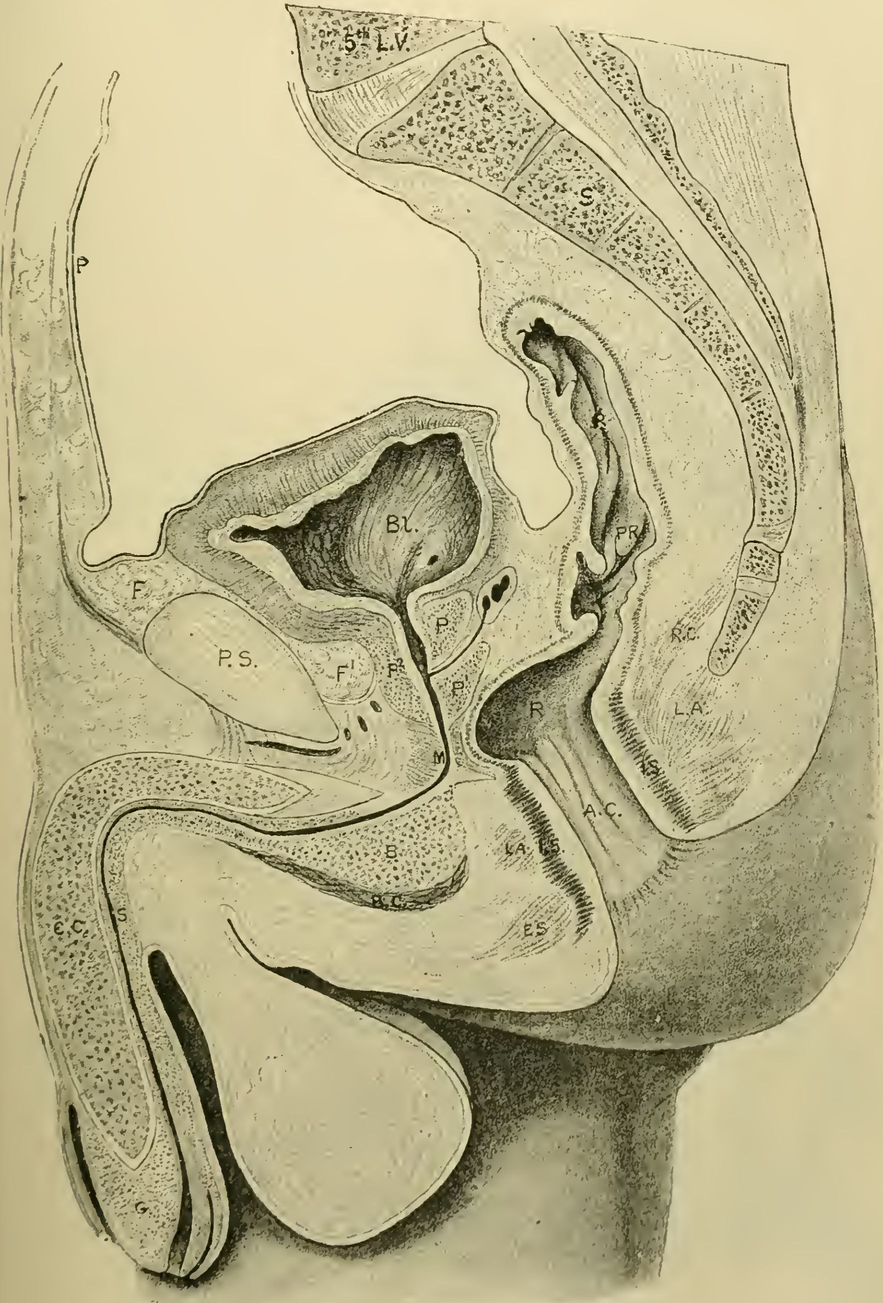


Fig. 250.—Median section of male pelvis, penis, and scrotum. (J. S.) ⅔.

C.C., corpus cavernosum; S, corpus spongiosum; B, its bulb; G, part forming the glans penis. For the other lettering, see p. 114.

Upon the body of the penis the skin is thin, free from fat, and, in the anterior two-thirds of its length, from hairs also ; in these respects differing remarkably from

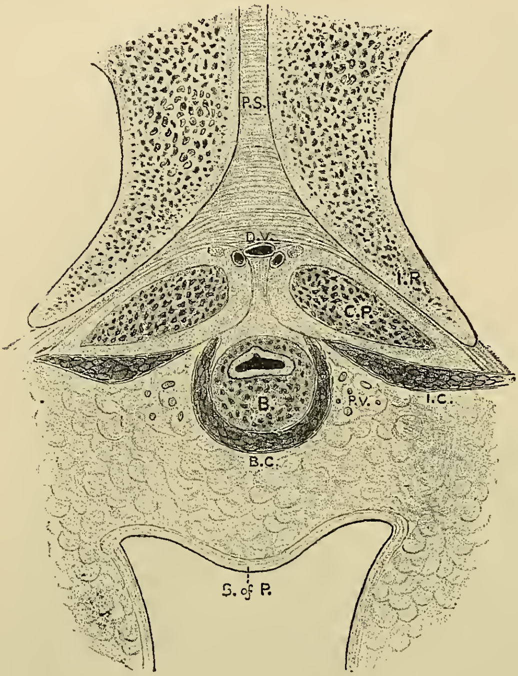


Fig. 251.—Transverse section passing from above downwards and backwards through pubic symphysis, root of penis, and skin of perineum. (J.S.) $\frac{1}{1}$.

P.S., pubic symphysis ; I.R., inferior ramus of pubis (the ramus of the ischium and the ischial tuberosity are posterior to the plane of this section) ; C.P., crus penis ; B, bulb of corpus spongiosum ; I.C., ischio-cavernosus muscle ; B.C., bulbo-cavernosus muscle ; P.V., superficial perineal vessels and nerves ; S. of P., skin of perineum ; D.V., dorsal vein of penis with an artery and a nerve on each side.

that on the pubes, which is thick, covers a large cushion of fat, and, after puberty, is beset with hairs : the skin of the penis is moreover very movable and distensible, and is of a darker colour than the skin generally. At the free margin of the prepuce the integument changes its character, and approaches that of a mucous membrane, being red, thin, and moist. Numerous sebaceous glands are collected round the cervix of the penis and corona glandis ; they are named the *glands of Tyson*, or *glandulæ odoriferæ*, their secretion having a peculiar odour.

Upon the surface of the glans the integument again changes its character ;

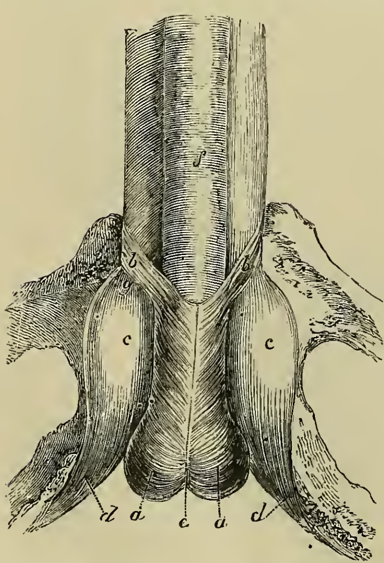


Fig. 252.—Root of the penis attached to the rami of the pubes and ischium (from Kobelt). $\frac{2}{3}$.

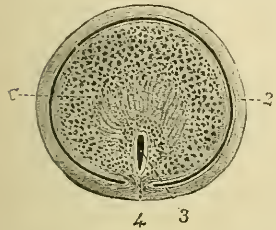
a, *a*, ejaculator urinæ muscle covering the bulb of the spongy body of the urethra, with at *e*, posteriorly, a median notch ; *b*, *b*, anterior slips of the bulbo-cavernosus muscle passing round the sides of the corpora cavernosa ; *c*, *c*, crura of the penis, with an oval dilatation or bulb of the corpus cavernosum; *d*, *d*, ischio-cavernosi or erectores penis muscles ; *f*, corpus spongiosum urethræ.

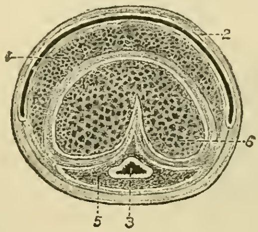
it contains no glands, but is beset with large vascular and nervous papillæ, and it adheres most intimately and immovably to the spongy tissue of the glans.

Beneath the skin, on the body of the penis, the ordinary superficial fascia is very distinct ; it is continuous with that of the groin, and also with the dartos tissue of the scrotum. Near the root of the organ there is a dense band of fibro-elastic tissue, named the *suspensory ligament*, lying amongst the fibres of the superficial fascia ; it is triangular in form ; its anterior border is free, its upper border is connected with the fore part of the pubic symphysis, and below it runs down upon the dorsum of the penis.

The integuments of the penis are supplied with blood by branches of the *dorsal artery of the penis* and *external pudic ;* the veins join the *dorsal* and *external pudic* veins. Their nerves are derived from the *dorsal* and *internal superficial perineal* branches of the *pudic nerves.*

The **corpora cavernosa** form the principal part of the body of the penis. They are two cylindrical bodies placed side by side, flattened on their median aspects, and closely united and in part blended together along the middle line in the anterior three-fourths of their length ; whilst at the back part, in contact with the symphysis pubis, they separate from each other in the form of two bulging and then tapering processes named *crura,* which, extending backwards, are attached to the pubic and ischial rami, and are invested by the erectores penis or ischio-cavernosi muscles. The enlarged portions at the root, named by Kobelt the *bulbs of the corpora cavernosa,* attain a much greater proportionate development in some quadrupeds than in man. In front, the corpora cavernosa are closely bound together into a





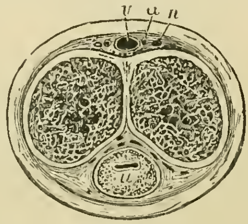


Fig. 253.—Transverse section of the glans penis in a distended state, ½ an inch behind the meatus. (J. S.)

1, glans penis ; 2, prepuce ; 3, urethra ; 4, frænum of the prepuce.

Fig. 254.—Transverse section of the glans penis in a distended state, ⅞ of an inch behind the meatus. (J. S.)

1, glans penis ; 2, prepuce ; 3, urethra ; 5, corpus spongiosum ; 6, corpus cavernosum.

Fig. 255.—Transverse section of the body of the penis in the distended state (altered from Henle).

The outer outline indicates the integument surrounding the deeper parts ; the erectile tissues of the corpora cavernosa and the septum pectiniforme are shown in section ; *u,* placed on the section of the spongy body, below the urethra ; *v,* the single dorsal vein ; *a,* the dorsal artery, and *n,* the nerve of one side.

blunt conical extremity, which is covered by the glans penis and firmly connected to its base by fibrous tissue.

The under surface of the united cavernous bodies is marked by a longitudinal groove, in which is lodged the corpus spongiosum. The upper or anterior surface is also marked with a slight median groove in which the dorsal vein of the penis is situated, and near the root is attached to the pubes by the suspensory ligament.

Structure.—The median septum between the two corpora cavernosa is thick and complete near the root of the penis ; but further forward it becomes thinner, and only imperfectly separates their cavities, for it exhibits, particularly towards the anterior extremity, numerous clefts, extending from the dorsal to the urethral edge, and admitting of a free communication between the erectile tissue of the two sides. From the direction of these slits, the intermediate white portions of the septum resemble somewhat the teeth of a comb, and hence the partition has received the name of *septum pectiniforme.*

The external fibrous investment of the cavernous structure is white and dense, from one to two millimetres thick, and very strong and elastic. It is composed for the most part of longitudinal bundles of shining white fibres, with numerous well-developed elastic fibres, enclosing the two corpora cavernosa in a common

covering; and internal to this, each corpus cavernosum is surrounded by a layer of circular fibres, which enter into the formation of the septum.

From the interior of the fibrous envelope, and from the sides of the septum, numerous lamellæ, bands, and cords, composed of fibrous elastic and plain muscular tissue, and named *trabeculæ*, pass inwards, and run through and across the cavity in all directions, thus subdividing it into a multitude of interstices, and giving the entire structure a spongy character.

Fig. 256. — SECTION OF ERECTILE TISSUE OF PENIS IN A NON-DISTENDED CONDITION (Cadiat).

a, trabeculæ of connective tissue with many elastic fibres and bundles of plain muscular tissue cut across (*c*); *b*, venous spaces.

The trabeculæ, whether lamelliform or cord-like, are larger and stronger near the circumference than along the centre of each cavernous body, and they also become gradually thicker towards the crura. The interspaces, conversely, are larger in the middle than near the surface; their long diameter is, in the latter situation, placed transversely to that of the penis: and they become larger towards the forepart of the penis. They are occupied by venous blood, being in reality large cavernous veins, and are lined by a layer of flattened epithelium similar to that lining other veins.

Fig. 257.—PORTION OF THE ERECTILE TISSUE OF THE CORPUS CAVERNOSUM MAGNIFIED, SHOWING THE AREOLAR STRUCTURE AND THE VASCULAR DISTRIBUTION (from J. Müller).

a, a small artery supported by the larger trabeculæ, and branching out on all sides; *c*, the tendril-like arterial tufts or helicine arteries of Müller; *d*, the areolar structure formed by the finer trabeculæ.

The intertrabecular spaces thus form a labyrinth of intercommunicating venous areolæ divided by the trabecular tissue, and opening freely from one corpus cavernosum to the other through the septum, especially in front. The blood is carried away from these spaces by two sets of veins, the one set joining the prostatic plexus and pudendal veins; the others passing into the dorsal vein. Of these last some issue from between the corpus cavernosum and the spongy body of the urethra, encircling the penis nearly at right angles, while others pass more directly into the dorsal vein from the upper surface.

The principal arteries of the corpora cavernosa are the cavernous branches of the pudic arteries (profundæ penis), of the right and left sides; but the dorsal artery of

the penis also sends small twigs through the fibrous sheath of the corpora cavernosa, along the upper surface, especially in the fore part of the penis. Within the cavernous tissue, the numerous branches of arteries are supported by the trabeculæ in the middle of which they run, and terminate in branches of capillary minuteness which open into the intertrabecular spaces; some of the arterial twigs project into the spaces, and form peculiar curling and somewhat dilated vessels, which

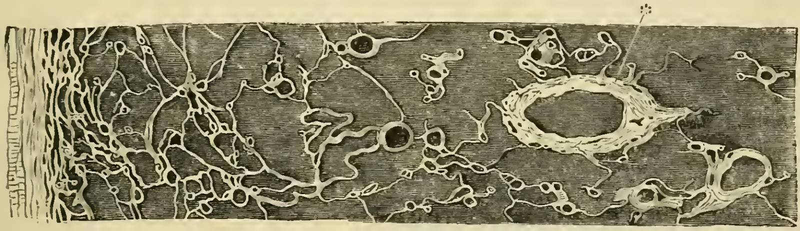


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Fig. 258.—Part of a section of one of the corpora cavernosa, injected from the deep artery of the penis (Henle).

On the left is seen the fibrous tissue; at *, a section of the arteria profunda penis.

were named by J. Müller, *helicine arteries.* These are usually bound down by small fibrous bands (fig. 259,* *), and it appears to be due to this circumstance that these projecting vessels acquire a looped or tortuous aspect when distended with injection.

The helicine arteries are most abundant in the posterior part of the corpora cavernosa, and are found in the corresponding part of the corpus spongiosum also;

Fig. 259.—Helicine arteries with their sheaths, as seen with a low power (Henle).

A and B, from the corpus cavernosum penis; D, from the corpus spongiosum urethræ; C, transverse section of one of the helicine arteries; in this and the other figures the smaller lateral prolongations of the arterial vessels into the sheath are shown; * *, fasciculi of connective tissue passing off from the summit of two of the sheaths.

but they have not been seen in the glans penis. They are more distinct in the human subject than in animals, where they are often missed. Small capillary branches pass from them to supply the tissue of the enclosing sheath.

In addition to the blood which passes into the venous spaces from the capillary network of the sheath and trabeculæ some small arteries are said by C. Langer to open directly into the larger venous spaces.

The **corpus spongiosum urethræ** commences below the triangular ligament of the perineum, where it is placed between the diverging crura of the corpora cavernosa, and somewhat behind their point of junction. The enlarged and rounded posterior extremity is named the *bulb*, and projects backwards somewhat beyond the urethra. It extends forwards as a cylindrical, or slightly tapering body, lodged in the groove on the under side of the united cavernous bodies, as far as their blunt conical anterior extremity, over which it expands so as to form the glans penis already described. In the whole of this extent it encloses the urethra.

The posterior bulbous part, or *bulb of the urethra*, varies in size in different subjects. It receives an investment from the triangular ligament on which it rests, and is embraced by the ejaculator urinæ, or bulbo-cavernosus muscle. The posterior extremity of the bulb exhibits, more or less distinctly, a subdivision into two lateral portions or lobes, separated by a slight furrow on the lower surface, and by a slender fibrous partition within, which extends for a short distance forwards ; in early infancy this is more marked. It is above this part that the urethra, having pierced the triangular ligament, enters the bulb, surrounded obliquely by a portion of the spongy tissue, named by Kobelt the *colliculus bulbi*, from which a layer of venous erectile tissue passes back upon the membranous and prostatic portions of the urethra to the neck of the bladder, lying closely beneath the mucous membrane. At first the urethra is nearer the upper than the lower part of the corpus spongiosum, but it soon gains and continues to occupy the middle of that body.

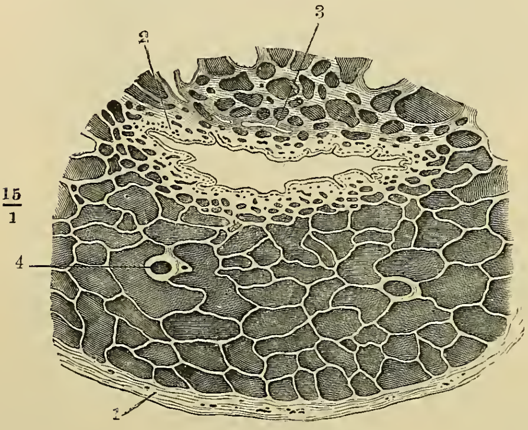

Fig. 260.—Section of the corpus spongiosum injected from its artery (Henle).

1, fibrous tunic of the corpus spongiosum ; 2, mucous membrane of the urethra ; 3, section of a lacuna of the mucous membrane ; 4, section of an artery.

According to the observations of Retterer, which are founded mainly upon a study of the development of the organ, the glans penis is only formed as to the part immediately encircling the urethra by true corpus spongiosum, the greater portion being developed from integumental tissue, which has become very vascular and cavernous, and which has united with the anterior ends both of the corpora cavernosa and of the corpus spongiosum ; the vascular connection with the latter being however by far the most complete.

Structure.—This is essentially the same as that of the corpora cavernosa, but with a much less developed fibrous framework. Like the corpora cavernosa, it is distended with blood during erection, but it never acquires the same rigidity. The fibrous tunic (fig. 260, 1) is much thinner, is less white in colour, and contains more elastic tissue ; the trabeculæ are finer and more equal in size ; the areolæ are smaller, more uniform, and directed for the most part with their long diameter in the line of that of the penis ; in the glans, the meshes are smallest and most uniform. Plain muscular fibres immediately surround the canal of the urethra, and also form part of the external coat of the spongy substance.

Blood-vessels.—Arteries.—A considerable artery derived from the *internal pudic* enters the bulb on each side, and supplies the greater part of the spongy body, sending branches as far as the glans penis, but this part is chiefly supplied by branches from the *arteria dorsalis*. Besides these, there is another but much smaller branch of the pudic artery, entering the bulb on the upper surface, about an inch from its posterior extremity, and running forwards in the corpus spongiosum to the glans (Kobelt). The arteries open into the venous spaces chiefly if not entirely by the intervention of capillaries. **Veins** issue from the glans and adjoining part of the spongy body, to end in the *vena dorsalis penis ;* those of the rest of the spongy body for the most part pass backwards through the bulb, and end in the *prostatic*

and *pudic venous plexuses;* some emerge from beneath the corpora cavernosa, anastomose with their veins, and end partly in the *cutaneous veins of the penis and scrotum*, and partly in the *pudic* and *obturator* veins.

The **lymphatics** of the penis form a dense network on the skin of the glans and prepuce, and also underneath the mucous lining of the urethra. They pass chiefly into the inguinal glands. Deep-seated lymphatics are also described as issuing from the cavernous and spongy bodies, and passing under the pubic arch with the deep veins, to join the lymphatic plexuses in the pelvis.

The **nerves** of the penis are derived from the dorsal and superficial perineal branches of the *pudic nerve* and from the *hypogastric plexus* of the sympathetic. The former are distributed to the skin and mucous membrane, the latter entirely to the cavernous and spongy bodies. Simple and compound end-bulbs (genital corpuscles) occur numerously on the nerves of the penis, and Pacinian bodies have been found on the nerves of the glans (see Vol. I., Part 2, p. 338).

URETHRA OF THE MALE.

The male urethra extends from the neck of the bladder to the extremity of the penis. Its total length when moderately stretched is about $8\frac{1}{2}$ inches (20.4 c.m.), but it varies with the length of the penis, and the condition of that organ. Except during the passage of urine or semen the walls of the canal are in close apposition, the outline of the urethral cleft being vertical in the glans penis, transverse in the body of the penis, and crescentic about the middle of the prostatic part. Its diameter when moderately distended differs at different parts, as will be stated more particularly hereafter. The tube consists of a continuous mucous membrane, supported by an outer layer of submucous tissue connecting it with the several parts through which it passes. In the submucous tissue there are, throughout the whole extent of the urethra, two layers of plain muscular fibres, the inner fibres disposed longitudinally, and the outer in a circular direction. The urethra may be divided into two parts, a *urinary* and a *uro-genital*. The urinary portion is about half an inch in length and extends from the vesical orifice to the openings of the common ejaculatory ducts. The uro-genital part, as its name implies, serves as a channel for both the urine and the spermatic fluid. It comprises the remaining and much the longer division of the urethra.

More commonly, however, the urethra is described under the three divisions of the *prostatic*, *membranous* or *muscular*, and *spongy* or *penile* portions.

1. The first, or **prostatic portion,** is the part which passes through the prostate gland. It is about $1\frac{1}{4}$ inches in length, is the widest part of the canal, and is wider in the middle than at either end: at the neck of the bladder its diameter is nearly one-third of an inch, in the next part it widens a little, so as to be rather more than this (in old persons nearly half an inch), farther on it diminishes, until, at its inferior limit, it is smaller than at its commencement. Its direction is vertical or very nearly so. Though enclosed in the firm glandular substance, it is more dilatable than any other part of the urethra; but immediately at the neck of the bladder, it is much more resistant. The transverse section of the urethra, as it lies in the prostate, is curved with the convexity forwards.

The lining membrane of the prostatic portion of the urethra is thrown into longitudinal folds, when not distended by fluid. Towards the neck of the bladder, a slight elevation on the posterior surface passes back into the uvula vesicæ. Somewhat in advance of this, and continued from it along the floor (posterior wall) of the passage, projects a narrow median ridge, about three quarters of an inch in length, and one eighth of an inch in its greatest height; this ridge gradually rises into a peak, and sinks down again at its anterior or lower end; it is formed by an elevation of the

mucous membrane and subjacent tissue. This is the crest of the urethra (*crista urethræ*), which also receives the names of *colliculus seminalis, caput gallinaginis* and *verumontanum*. On each side of this ridge the surface is slightly depressed, so as to form a longitudinal groove, named the *prostatic sinus*, the floor of which is pierced by numerous foramina, the orifices of the prostatic ducts. Through these a viscid fluid oozes out on pressure; the ducts of the middle lobe open above the urethral

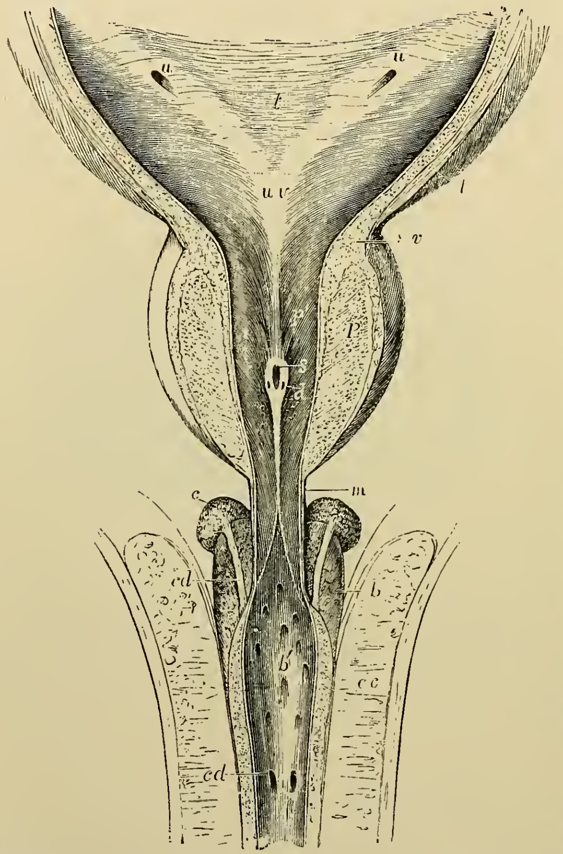

Fig. 261.—The lower part of the bladder and the prostatic, membranous, and bulbous parts of the urethra opened from above. (Allen Thomson.)

A portion of the wall of the bladder and the anterior part of the prostate gland have been removed, the corpora cavernosa penis have been separated in the middle line and turned to the side, and the urethra has been slit up; the bulb is left entire below, and upon and behind it the glands of Cowper with their ducts have been exposed. *t*, placed in the middle of the trigonum vesicæ; *u*, *u*, oblique apertures of the ureters; from these an elevation of the wall of the bladder is shown running down to *u v*, the uvula vesicæ; *l*, the longitudinal muscular fibres of the bladder passing down upon the prostate; *s v*, the circular fibres of the sphincter; *p*, the glandular part of the prostate; *p'*, the prostatic portion of the urethra; from the uvula vesicæ a median ridge is seen descending to the caput gallinaginis, in which *s* indicates the opening of the prostatic utricle, and *d*, that of one of the ejaculatory ducts; *m*, the commencement of the membranous portion of the urethra; *b*, the bulb of the spongy body; *b'*, the bulbous part of the urethra; *c*, one of Cowper's glands; *c d*, *c d*, course and orifice of its duct lying upon the bulb, and passing forward between the spongy body and the urethra, into which along with its fellow it opens; *c c*, one of the corpora cavernosa.

crest, and some others open below it. The prostatic urethral mucous membrane is covered by a laminated epithelium like that of the bladder.

At the fore part of the most elevated portion of the crest, and exactly in the middle line, is the orifice of a blind recess, upon or within the lateral margins of which are placed the slit-like openings of the common seminal or ejaculatory ducts, one at each side. This median opening leads into the prostatic utricle, which has been named also *sinus pocularis*, *vesicula prostatica* or *uterus masculinus*. It was first described by Morgagni, and corresponds with the vagina and uterus in the female, its prominent lateral lips being supposed to represent the hymen.

The vesicle forms a cul-de-sac running upwards or backwards, for a distance of from a quarter to half an inch (6 to 12 mm.). Its orifice forms a longitudinal cleft about 2 or 3 mm. in length, but the vesicle increases somewhat in diameter towards its farther end or fundus. The narrow portion runs in the urethral crest, and its fundus lies behind and beneath the middle lobe, and in some cases reaches to the posterior surface of the prostate gland. Its parietes, which are distinct, and of

some thickness, are composed of fibrous tissue and mucous membrane, together with a few muscular fibres, and enclose on each side the ejaculatory duct; numerous

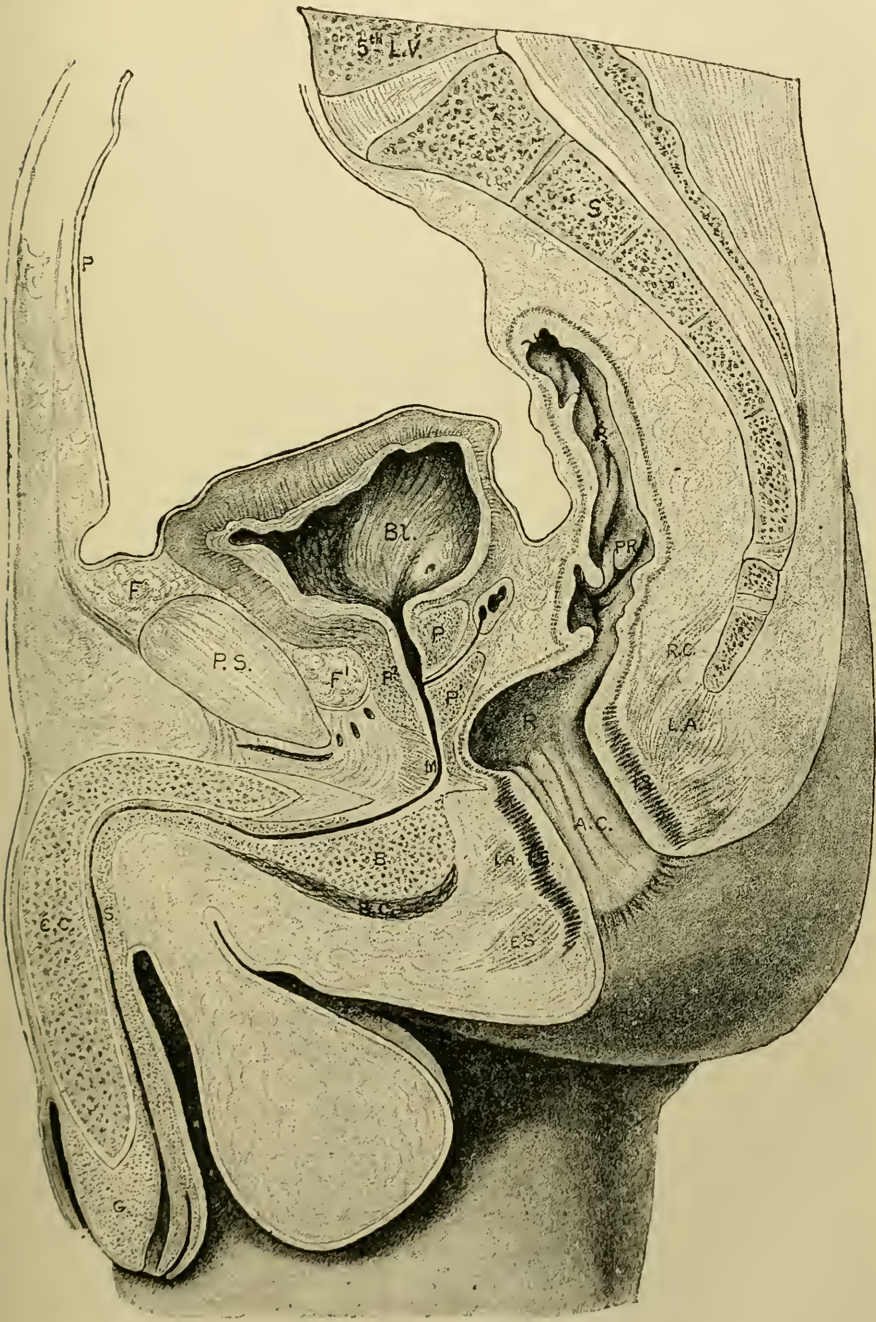

Fig. 262.—Median section of the male pelvis and urethra. (J. S.) ⅜

bl., bladder; p.s., pubic symphysis; f., fat; p, p′, prostate; bu, bulb of corpus spongiosum; m, membranous portion of urethra; s, spongy portion; g, glans penis. For other references see p. 114

small ramified and convoluted glands open on its inner surface. The epithelium is columnar and is by some authors stated to be ciliated. There are small glands opening into its cavity near the entrance into the urethra. The caput gallinaginis contains some well-marked erectile and plain muscular tissue, and it has been supposed that this eminence, when distended with blood, may offer an obstacle to the passage of the semen backwards into the bladder.

2. The **membranous portion** of the urethra comprises the part between the apex of the prostate and the bulb of the corpus spongiosum. It is three quarters of an inch (18 mm.) long, but about half an inch of its posterior surface is covered by the bulb of the corpus cavernosum which projects backwards over it. This membranous portion is the narrowest division of the urethra. In the middle its diameter is one-fifth of an inch (5 mm.) : at the end not quite so much. It is directed downwards and slightly forwards beneath the pubic arch, the anterior slightly concave surface being distant nearly an inch from the pubic symphysis, leaving an interval, occupied by the dorsal vessels and nerves of the penis, by areolar tissue, and some muscular fibres. Its posterior convex surface is turned towards the rectum. It lies between the two layers of the triangular ligament, and both these fibrous membranes are prolonged upon it, the one backwards and the other forwards. Between these two layers the urethra is surrounded by erectile tissue, by some veins, and also by plain muscular tissue, and the fibres of the compressor urethræ muscle. On each side are Cowper's glands. The plain muscular fibres of this portion of the urethra are continued over the outer and inner surfaces of the prostate into the muscular fibres of the bladder posteriorly, and into those of the spongy portion of the urethra anteriorly (Hancock).

3. The **spongy portion** of the urethra, by far the longest and most variable in length and direction, includes the remainder of the canal, or that part which is surrounded by the erectile tissue of the corpus spongiosum. Its length is about six inches (150mm.). The direction of the spongy portion of the urethra varies in different parts of its course and under different conditions. Thus it inclines forwards and downwards for a short distance in front of the superficial layer of the triangular ligament, and then turns forwards and somewhat upwards to about the middle of its length, where in the flaccid condition of the penis it usually bends sharply downwards to the external meatus. During erection of the penis or when this organ is drawn forwards, as in passing a catheter, this temporary curve is obliterated and the spongy part is straight frcm the external meatus to the neighbourhood of the bulb. The part contained within the bulb, sometimes distinguished as the *bulbous portion*, or *sinus*, is somewhat dilated. The succeeding portion, as far as the glans, is of uniform diameter, being intermediate in this respect between the bulbous and membranous portions. The cross section of its canal appears like a transverse slit. The canal of the urethra in the glans has, on the contrary, when seen in a cross section, the form of a vertical slit ; in this part, which is from one-third to half an inch in length, the canal is again dilated, forming what is named the *fossa navicularis*.

Lastly, at its orifice, which is a vertical fissure from one-fifth to one-fourth of an inch (5 to 6 mm.) in extent, and bounded by two small lips, the urethra is again contracted and reaches its narrowest dimensions. From the resistant nature of the tissues at its margin, this opening does not admit so large a sound or catheter as even the membranous portion of the canal.

The **mucous membrane** of the urethra possesses a lining of epithelium, of which the superficial cells are long and columnar, except for a short distance (5 to 8 mm.) from the orifice, where they are squamous, and where the subjacent membrane is beset with papillæ. The epithelium rests on a basement membrane. Outside the mucous membrane there is a layer of convoluted vascular structure, and

external to that a double layer of plain muscular fibres, the inner disposed longitudinally and the outer circularly, separating it from the proper substance of the spongy body.

The whole lining membrane of the urethra, except near the orifice, is beset with small racemose mucous glands and follicles, commonly named the *glands of Littré*, the ducts of which pass obliquely forwards through the membrane. They vary much in size and in the extent to which their cavities are ramified and sacculated, some being quite simple. Besides these there are larger recesses or *lacunæ*, opening by oblique orifices turned forwards, or down the canal. These are most abundant along the floor of the urethra, especially in its bulbous part. One large and conspicuous recess, situated on the upper surface of the fossa navicularis, is named the *lacuna magna*. A median fold of the membrane rising from the inferior surface of this part of the urethra has been named the *valve of the fossa navicularis*.

Stratified concrements like those met with in the prostate (see below) are also found in old subjects in the glandular recesses of the urethra (Robin and Cadiat).

Cowper's glands.—In the bulbous portion of the urethra, near its anterior end, are the two openings of the ducts of *Cowper's glands*. These small glandular bodies (fig. 261, *c*) are seated above the bulb, behind the membranous portion of the urethra, between the two layers of the triangular ligament, the inferior layer supporting them against the urethra. The arteries of the bulb pass above, and the transverse fibres of the compressor urethræ beneath these glands. They form two small firm rounded masses, about the size of peas, and of a deep yellow colour. They are compound racemose glands, composed of several small lobules held together by a firm investment. This latter, as well as the walls of the ducts, contains muscular tissue. The epithelium of the acini consists of clear columnar cells, with a reticular protoplasm, staining like the cells of mucous glands. The ducts are lined with cubical epithelium. The ducts unite outside each gland to form a single excretory duct (fig. 261, *c d*). These ducts run forward near each other for about an inch or an inch-and-a-half, first in the spongy substance and then beneath the mucous membrane, and terminate in the floor of the bulbous part of the urethra by two minute orifices opening obliquely. The glands secrete a viscid fluid, the use of which is not known; they appear to diminish in old age; sometimes there is only one present, and it is said both may be absent.

Occasionally there is a third glandular body in front of and between Cowper's glands; this has been named the *anterior prostate* or *ante-prostatic gland*.

The muscles in connection with the urethra and penis have been already described with the muscles of the perinæum in Vol. II., Part 2.

PROSTATE GLAND.

The prostate gland (figs. 262, 263, 264) is an organ connected with both the urinary and male genital ducts, but it primarily belongs to the latter, being one of the accessory male organs of generation. It atrophies in the adult after the testicles are excised, and when these organs are removed in infancy it remains undeveloped. In animals it enlarges, like the testicles, during the breeding season.

It is a firm, glandular, and muscular body, comparable in size and shape to a chestnut, situated in the pelvis, and traversed by the first part of the urethra and by the common ejaculatory ducts. It has a base, an apex, an anterior, a posterior and two lateral surfaces. The *base* is situated immediately below the neck of the bladder, while the *apex* is above the superior layer of the triangular ligament. Its *posterior surface*, which is flat and larger than the anterior, lies against the second part of the rectum so that it can readily be felt by passing the finger into that organ. The *anterior surface* is convex and is placed about half-an-inch behind the lower part of the pubic symphysis from which it is separated by some fat, a plexus

of veins and the pubo-prostatic ligaments. The *lateral surfaces* are convex and prominent, and are covered by the anterior portions of the levatores ani muscles, which pass backwards on each side from the pubis and the superior layer of the triangular ligament and embrace the sides of the prostate, but are separated from the gland by a plexus of veins. The urethra passes through the prostate from its base to its apex in the median plane and rather nearer the anterior than the posterior surface, being generally about a quarter of an inch (6mm.) from the former and

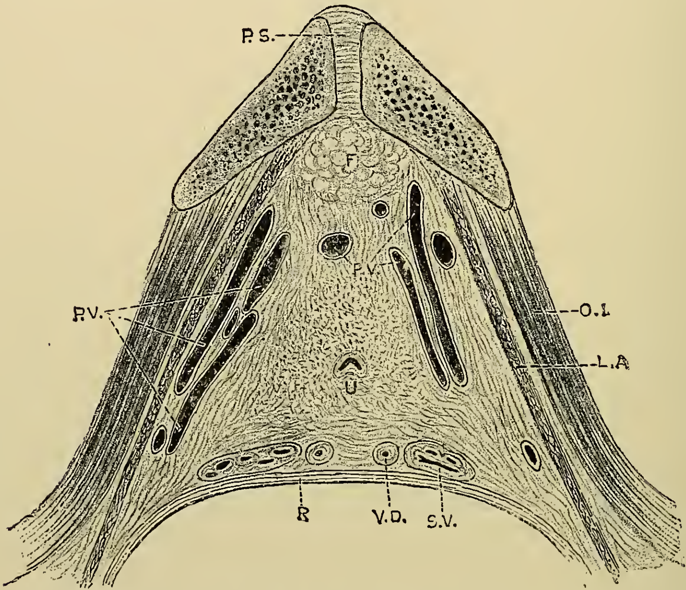

Fig. 263.—Horizontal section of male pelvis passing through the prostate gland at its junction with the bladder. The rectum was distended with fæces. (J. S.). $\frac{1}{1}$

p. s., pubic symphysis ; o. i, obturator internus muscle ; l. a., levator ani muscle ; p. v., prostatic plexus of veins ; f, retro-pubic pad of fat ; u, upper part of prostatic urethra ; r, anterior wall of rectum ; vd., vas deferens ; s. v., seminal vesicle.

nearly half an inch (12mm.) from the latter. The prostate is also pierced by the two common ejaculatory ducts which enter at a median depression situated at the upper part of the posterior surface and, passing downwards and forwards in

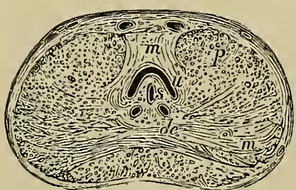

Fig. 264.—Transverse section of the prostate gland through the middle. (Allen Thomson.)

u, the urethra into which the eminence of the caput gallinaginis rises from below; *s*, the utricle cut through ; *d c*, the ejaculatory ducts ; *m*, superiorly, the deep sphincter muscular fibres ; *m*, lower down, intersecting muscular bands in the lateral lobes of the prostate ; *p*, glandular substance.

close contact with one another, open on the posterior wall of the prostatic portion of the urethra. In a median section (fig. 262) the prostate is therefore seen to be divisible into three parts, one in front and two behind the urethra. Of the two posterior portions, one lies above and in front, and the other below and behind, the channel for the ejaculatory ducts.

The prostate is usually described as consisting of three lobes, two lateral and one median. The *lateral lobes* form the great mass of the gland and are united with one

another in front of the urethra, and also behind the urethra below the ejaculatory ducts. The *middle lobe* lies behind the upper portion of the urethra, below the apical portion of the trigone of the bladder and above the common ejaculatory ducts. At the sides it passes without any line of demarcation into the lateral lobes. This part of the prostate is of considerable surgical interest since, when enlarged, it may seriously interfere with micturition. Its title to be regarded as a distinct "lobe" is disputed. Sometimes it projects backwards, as a rounded prominence, between the bladder and the vasa deferentia, but, according to H. Thompson, this only occurs when it is pathologically enlarged. According to J. Griffiths it contains, in some subjects, glandular tissue, the ducts of the glands being distinguishable from those of the lateral lobes by opening on the posterior surface of the upper part of the prostatic urethra in and near the middle line. In other cases neither glandular tissue nor ducts are present in this position. The prostatic part of the urethra receives not only the openings of the seminal and prostatic ducts, but also, as has already been more particularly described, that of a small blind recess, called the *sinus pocularis* or *prostatic utricle,* which passes backwards in close relation with the ejaculatory ducts.

Size and Weight.—The longest diameter of the prostate is the transverse which measures near the base of the organ about one and a half inches (36 mm.), its vertical extent is about one and a quarter inches (30 mm.), and its antero-posterior nearly three-quarters of an inch (18 mm.) These diameters, however, are liable to alteration according to the condition of the bladder and rectum. Thus distension of the bladder tends to diminish its vertical extent, while a dilatation of the lower part of the rectum will compress the organ from before backwards, and increase its vertical and transverse diameters. Its average weight may be estimated, according to H. Thompson, at about four and a half to four and three-quarter drachms (20·5 grammes, Bischoff).

Structure.—The prostate gland is covered externally by a dense fibrous coat, which is continuous with the recto-vesical fascia, and with the superior layer of the

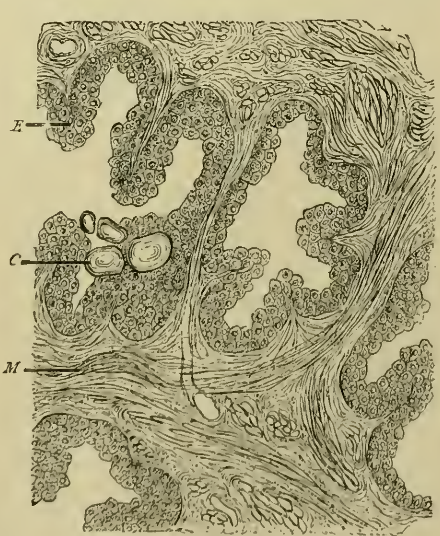

Fig. 265.—Section of some of the gland-tubes of the prostate. (Heitzmann).
M, muscular tissue; *E*, epithelium; *C*, concretions.

triangular ligament. This fibrous capsule, which includes much plain muscular tissue, is divisible into two layers, between which the prostatic plexus of veins is enclosed (Adams). From the capsule trabeculæ extend through the gland towards the colliculus seminalis. The glandular substance is associated with a large quantity of plain muscular tissue, which forms the principal part of the stroma of the organ. This muscular tissue forms an external layer below the fibrous capsule, and extends everywhere through the glandular substance: there is also a strong layer of circular fibres continuous posteriorly with those of the bladder, and in front with the thin layer surrounding the membranous part of the urethra. The part of the prostate in front of the urethra is almost entirely muscular; in the hinder part the muscular substance is in greatest quantity near the bladder.

The glandular substance is spongy and yielding; its colour is reddish grey, or sometimes of a brownish hue. It consists of numerous tubular alveoli, which unite into a smaller number of excretory ducts. The epithelium is shortly columnar or vertical throughout, and there is a second layer of small cells next to the basement membrane. In the upper part of the gland the acini are smaller and more saccular; in the middle and lower parts the tubes are longer and convoluted at their ends. The capillary bloodvessels form a close network, as in other similar glands, on the ducts and acini, and the different portions of the gland are united by areolar tissue, and supported by processes of the deep layer of the fibrous capsule and by the muscular stroma. The ducts open by from twelve to twenty or more orifices upon the floor of the urethra, chiefly in the hollow on each side of the colliculus seminalis.

Vessels and Nerves.—Arteries.—The prostate is supplied by branches of the *vesical, hæmorrhoidal*, and *pudic* arteries. Its **veins** form a plexus imbedded in the fibrous covering round the sides and front of the gland, which is highly developed in old subjects. The veins communicate in front with the *dorsal vein of the penis*, and behind with branches of the *internal iliac vein*. **Lymphatics** ramify with the veins, between the two layers of the fibrous capsule. The **nerves,** which are derived from the *hypogastric plexus*, consist of both medullated and non-medullated fibres, and are interspersed with ganglion cells. Pacinian bodies have also been observed on the superficial nerves.

Secretion.—Examined after death, the prostatic fluid has a milky aspect, due to the admixture of a large number of epithelial cells, but probably, during life, it is more transparent. It is not a mucous secretion but, according to Adams, the fluid has an acid reaction, and presents, under the microscope, numerous granules, epithelial cells and nuclei. Some of the granules are composed of lecithin (Fürbringer, Jena. Sitzungsb., 1881).

Peculiarities according to age.—The prostate is very small at birth and it remains comparatively so until puberty, when in common with the other generative organs it undergoes a considerable increase in size. Thus, according to Gross, it weighs at birth 13 grains, at the 4th year 23 grains, at the 12th 43 grains, at the 14th 58 grains, and at the 20th 260 grains (17 grammes).

The glandular tissue of the prostate is developed by epithelial outgrowths from the posterior wall of the urethra at the sides of the orifices of the primitive genital ducts, both Müllerian and Wolffian (Griffiths). These gland tubules grow outwards to form the lateral lobes of the prostate, and by their extension forwards and inwards, may meet in the median plane in front of the urethra. The amount of gland tissue in front of the urethra is very small in the child, and in some cases it is not developed in this situation at any period of life. Griffiths considers that the median lobe, when present, is not formed by a fusion of the lateral lobes behind the urethra, but arises independently by median outgrowths from the upper part of the posterior wall of the urethra. The prostate exhibits a marked tendency to undergo enlargement in old age, and its tubules frequently contain small laminated bodies which gradually become calcified (fig. 265, *c*.).

RECENT LITERATURE OF THE MALE REPRODUCTIVE ORGANS.

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REPRODUCTIVE ORGANS IN THE FEMALE.

The genital organs in the female consist of a pair of glands called the ovaries, and of certain passages leading from the peritoneal cavity to the exterior. These passages may be divided into a pair of lateral ducts, the *Fallopian tubes*, and a single

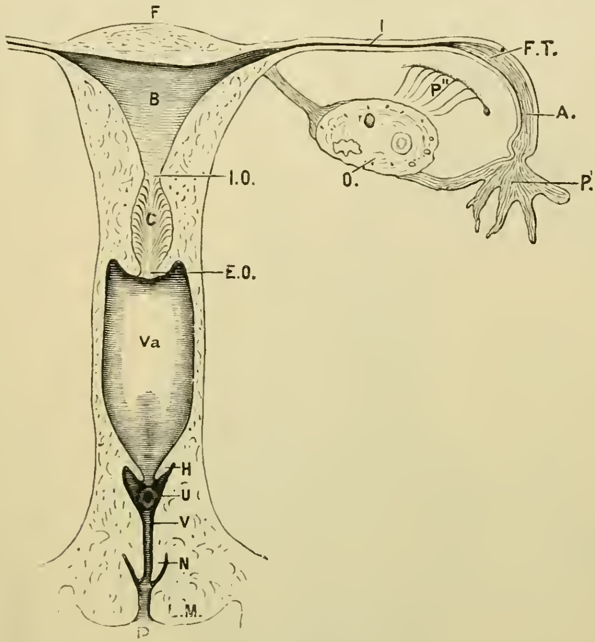


Fig. 266.—Diagram of female genital passages. Modified from Henle. (J. S.)

o., ovary ; p''., parovarium ; f.t., Fallopian tube ; p'., pavilion at fimbriated end of Fallopian tube ; a., ampulla of Fallopian tube ; i., isthmus of Fallopian tube ; f., fundus of uterus ; b., cavity of body of uterus ; i.o., os uteri internum ; c., cavity of cervix of uterus ; e.o., os uteri externum ; va., vagina ; h., hymen ; u., orifice of urethra ; v., vestibule ; n., labium minus ; l.m., labium majus ; p., pudendal or vulval cleft. The passage from u. to p. constitutes the uro-genital space.

median passage, which consists of three main portions named from above downwards the *uterus*, *vagina*, and *uro-genital space*, or *vulval cleft*. Fig. 266 shows diagrammatically the general relations of these parts. The structures which bound the uro-genital space constitute the *external genitals*, while those above the hymen are the *internal genitals*.

THE EXTERNAL GENITALS.

The **vulva**, or **pudendum**, is a general term for the external genitals (fig. 268). It includes the *mons Veneris*, the *labia majora* and *minora*, the *clitoris*, and the *hymen*. The *urethra* may also be described in connection with these parts.

The **mons Veneris** is an eminence formed by a mass of areolar and adipose tissue covered by skin provided with numerous hairs. It is situated in front of the upper part of the pubic symphysis.

The **labia majora** are two rounded folds of skin extending downwards and backwards from the mons to within about an inch of the anus. Each labium has an outer convex surface, resembling ordinary skin, covered with hairs, and an

inner smooth surface of a pinkish colour, which lies against the opposite labium. Within the substance of the fold there is found, besides fat, vessels, nerves, and glands, a tissue resembling that of the dartos in the scrotum of the male, to which the labia majora correspond. The labia majora, by their contact, generally conceal the other parts of the external genitals ; not unfrequently, however, in old persons

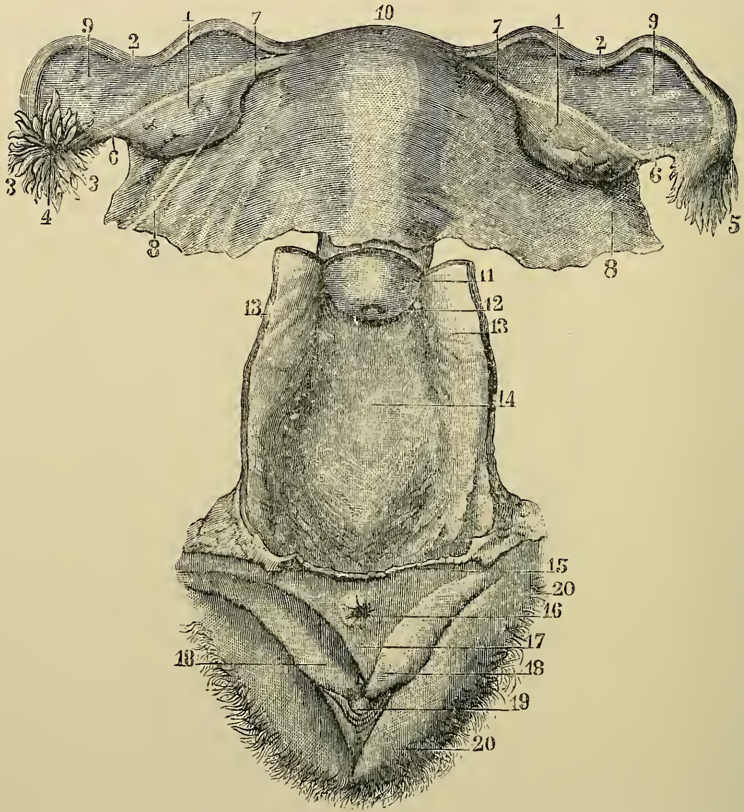


Fig. 267.—View of the female organs of generation from behind, the vagina being cut open and its walls turned aside. (Sappey.) ½.

1, ovaries ; 2, Fallopian tubes ; 3, 4, 5, their fimbriated extremities (4 points to the ostium abdominale) ; 6, ovarian fimbria ; 7, ligament of the ovary ; 8, 9, broad ligaments ; 10, uterus ; 11, its vaginal portion ; 12, os uteri ; 13, lateral and posterior walls of vagina reflected ; 14, its anterior wall ; 15, edge of hymen ; 16, orifice of urethra ; 17, vestibule ; 18, nymphæ ; 19, clitoris ; 20, labia majora.

the labia minora project forwards between the labia majora so as to be visible externally.

The **labia minora**, or **nymphæ**, are two narrow pendulous folds of skin, one on the inner surface of each labium majus. From their attached borders they extend downwards, having their outer surfaces in contact with the labia majora, and their inner surfaces against one another. Anteriorly each labium divides into two branches, the upper of which joins the prepuce of the clitoris, and the other its glans. Posteriorly the labium minus may end by gradually blending with the inner surface of the labium majus, but in some cases it can be traced backwards until it becomes continuous with a transverse fold of skin situated at the anterior edge of the perineum, and known as the *fourchette.* The nymphæ and fourchette resemble one another and differ from the labia majora in being devoid of fat. In young

subjects the labia minora are of a rosy-red colour, and look like a mucous membrane, but as age advances they become darker in colour and more like skin.

The **clitoris**, the homologue of the penis, is an erectile organ composed of two corpora cavernosa and a rudimentary glans. It differs from the penis in being much smaller, and in not being traversed by a urethra. The corpora cavernosa are separated behind where they constitute the crura of the clitoris, but they unite in front to form its body. Each crus is firmly attached to the inner aspect of the pubic arch superficial to the triangular ligament, and is covered by the ischio-cavernosus or erector clitoridis muscle. In the body of the clitoris the two corpora cavernosa are closely united by their flattened inner surfaces, the fibrous septum between them (*septum pectiniforme*) being incomplete. The body is fixed by a small suspensory ligament to the front of the symphysis pubis, from which point it extends downwards and backwards for about an inch and a half. Its extremity is surmounted by a small glans composed of spongy erectile tissue. The glans is imperforate, highly sensitive, and surrounded superiorly by a membranous fold, like the prepuce of the penis, while below it gives attachment to a small frænum. The prepuce and frænum are continuous with the labia minora.

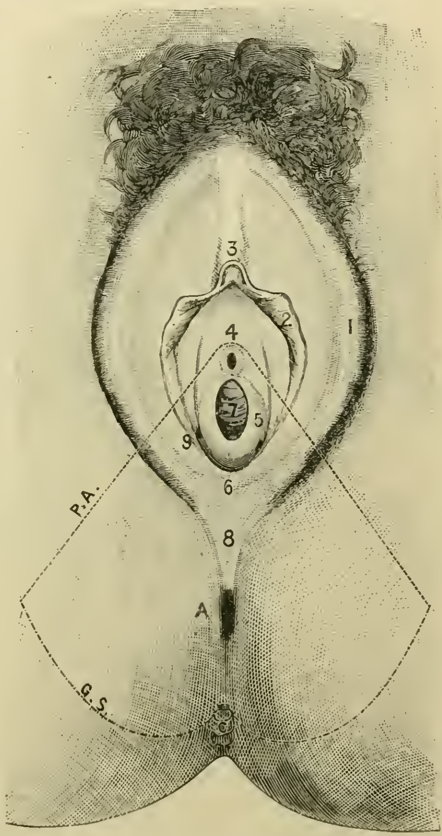


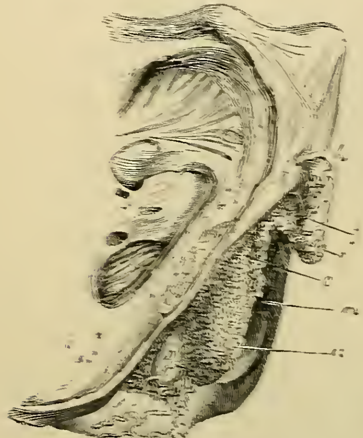
Fig. 268.—View of external genitals of adult female, with thighs abducted, and labia majora and minora separated. (J. S.)

1, labium majus; 2, labium minus; 3, preputium clitoridis; 4, vestibule; 5, hymen; 6, fourchette; 7, vaginal orifice; 8, base of perineal body; 9, opening of duct of gland of Bartholin; A., anus. Dotted line to show position of outlet of ligamentous pelvis; G.S., great sacro-sciatic ligament; P.A., pubic arch; C., coccyx.

Erectile tissue.—All the parts of the vulva are abundantly supplied with blood-vessels, and in certain situations there are masses composed of venous plexuses or erectile tissue, corresponding to those found in the male. Besides the corpora cavernosa and glans clitoridis just referred to, there are two oval masses of erectile tissue, the *bulbi vestibuli* (figs. 269 and 270, *a*). Each bulb is about an inch long, and lies in the side wall of the uro-genital space a little above the nymphæ and superficial to the triangular ligament. The bulbs are rather pointed at their upper extremities and rounded below; their inner aspects are partially covered by mucous membrane, while on the outer side they are embraced by the fibres of the bulbo-cavernosus muscle. Together they are equivalent to the bulb of the urethra in the male, which, it will be remembered, shows traces of a median division. In front of the bipartite bulb of the vestibule is a smaller plexus on each side, the vessels of which are directly continuous with those of the bulbi vestibuli behind, and of the glans clitoridis in front. This is the *pars intermedia* of Kobelt, and is regarded by him as corresponding with the

part of the male corpus spongiosum urethræ which lies between the bulb and the glans. It receives large veins coming direct from the nymphæ.

The **uro-genital space, or vulval cleft,** is a median fissure, which opens below on to the surface between the two labia majora, and receives at its upper part the orifices of the urethra and vagina. A portion of this space bounded in front by the glans clitoridis, behind by a transverse line at the level of the urethra, and at the sides by the labia minora, is called the *vestibule*. At the posterior part of the space there is a recess between the fourchette and the hymen, called the *fossa navicularis*. The more superficial part of the space bounded by the labia majora and minora, is lined by



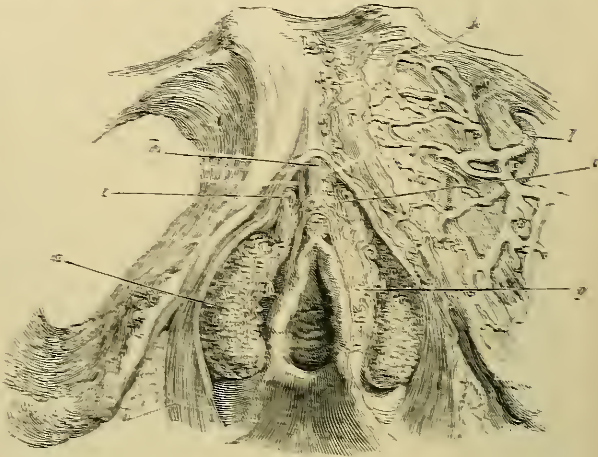


Fig. 269.—Lateral view of the erectile structures of the external organs in the female. (From Kobelt.)

The blood-vessels have been injected, and the skin and mucous membrane have been removed; *a*, bulbus vestibuli; *e*, plexus of veins named pars intermedia; *c*, glans clitoridis; *f*, body of the clitoris; *h*, dorsal vein; *l*, right crus clitoridis; *m*, vestibule; *n*, right gland of Bartholin.

Fig. 270.—Front view of the erectile structures of the external organs in the female. (From Kobelt.)

a, bulbus vestibuli; *b*, sphincter vaginæ muscle; *e*, *e*, venous plexus or pars intermedia; *f*, glans clitoridis; *g*, connecting veins; *h*, dorsal vein of the clitoris; *k*, veins passing beneath the pubes; *l*, the obturator vein.

skin, and the deeper part by mucous membrane, which is continuous with the mucous membrane of the urethra and vagina. According to Berry Hart, the line separating skin from mucous membrane runs from just below the prepuce of the clitoris backwards on each side along the base of the inner aspect of the labium minus to the outer aspect of the base of the hymen. The mucous membrane is smooth, reddish in colour, is covered by a scaly epithelium, and is provided with a considerable number of mucous crypts or follicles, and with glands which secrete an unctuous and odorous substance. Sebaceous glands are found beneath the prepuce and upon the labia majora and minora. Fine, downy hairs can be seen on the inner aspect of the labia majora, but none on the labia minora.

The **glands of Bartholin**, or of Duverney (fig. 269, *n*), corresponding to Cowper's glands in the male, are two reddish-yellow, round or oval bodies, measuring about half an inch in the longest diameter, lodged one on each side of the commencement of the vagina and beneath the inferior layer of the triangular ligament. Their ducts, which are long and simple, open one on each side a little in front of the fossa navicularis, by the side of the vaginal orifice, in the groove between the attached border of the hymen and the labium minus (Cullingworth). As a rule, the orifices of these ducts are too small to be distinctly recognised with the naked eye.

Blood-vessels.—Arteries.—The outermost parts of the vulva are supplied by the *superficial pudic* and *perineal* arteries ; the deeper parts and all the erectile tissues receive branches from the *internal pudic* arteries as in the male. The **veins** also in a great measure correspond ; there is a dorsal vein of the clitoris receiving branches from the glans and other parts as in the male ; the veins of the bulbus vestibuli pass backwards into the vaginal plexuses, and are connected also with the obturator

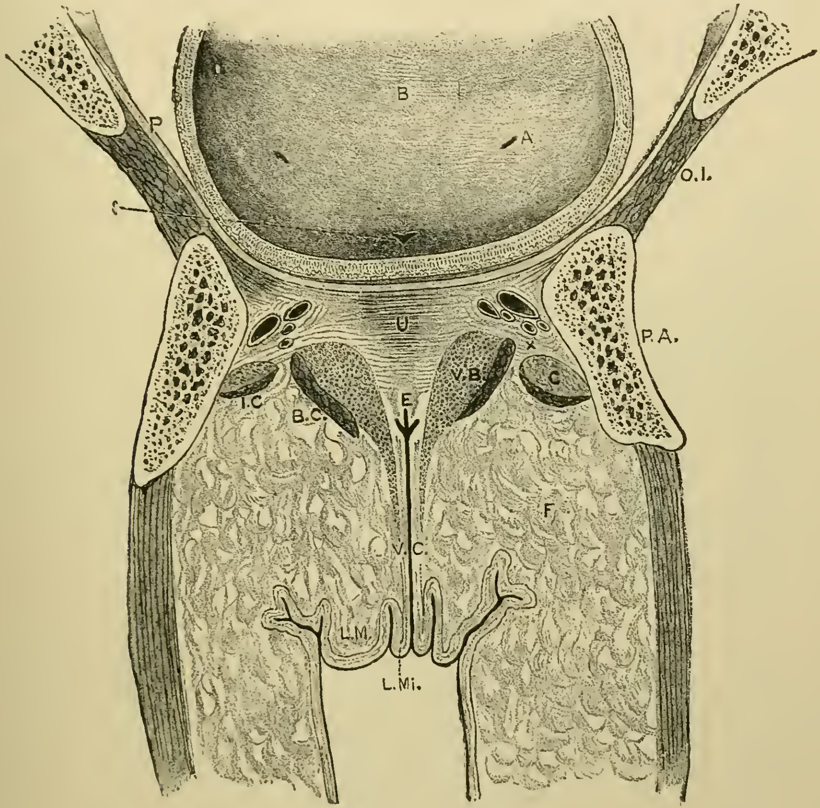


Fig. 271.—Transverse section passing from above downwards and slightly backwards through the anterior part of the pelvis of a woman aged 54 years : seen from the front. (J. S.) $\frac{1}{1}$

B. Bladder, cut across about half-an-inch in front of urethral orifice, I ; E, external urinary meatus, formed a vertical slit on a slight prominence ; A, opening of left ureter ; V.C., vulval cleft ; U, anterior wall of urethra ; V.B., vestibular bulb ; C, crus clitoridis ; B.C., bulbo-cavernosus muscle ; I.C., ischio-cavernosus muscle ; L.M., labium majus ; L.MI., labium minus ; P.A., pubic arch ; O.I., obturator internus muscle ; X., on triangular ligament ; P., pelvic fascia.

veins : above they communicate with the veins of the pars intermedia, those of the corpora cavernosa and the glans of the clitoris, and also with the vena dorsalis. The lymphatics accompany the blood-vessels.

Nerves.—Besides *sympathetic branches*, which descend along the arteries, especially for the erectile tissues, there are other nerves proceeding from the lumbar and sacral plexuses ; those from the former being branches of the *genito-crural*, and those from the latter of the *inferior pudendal* and *internal pudic* nerves, which last sends comparatively large branches to the clitoris. They terminate in the clitoris in peculiar tactile corpuscles (see Vol. I., Part 2, p. 338).

THE FEMALE URETHRA.

The female urethra is short as compared with that of the male sex, and corresponds to the part of the male urethra which extends from the bladder to the openings of the ejaculatory ducts. It is about an inch and a half in length, and is directed from above downwards and forwards anterior to and parallel with the vagina, with which its posterior wall is intimately blended. It is closed, except during micturition, by the apposition of the anterior and posterior walls. The transverse diameter of the closed tube is about a quarter of an inch, but the tube is capable of great distension, so that the index finger can be passed through it without causing any permanent incontinence (Berry Hart). The external orifice or meatus urinarius appears as a vertical slit with slightly prominent edges (see fig. 268, E), situated about an inch behind the glans clitoridis, immediately in front of the entrance to the vagina and below the lower edge of the pubic symphysis. The upper opening of the urethra is at the neck of the bladder.

Structure of the urethral wall.—The mucous membrane is whitish, except near the orifice ; it is raised into longitudinal folds, which are not entirely obliterated by distension, especially one which is particularly marked on the lower or posterior surface of the urethra. Near the bladder the membrane is soft and pulpy, with many tubular mucous glands. Lower down these increase in size and lie in groups between the longitudinal folds ; and immediately within and around the orifice, the lips of which are elevated, are several larger and wider crypts.

The lining membrane is covered with a stratified scaly epithelium, but near the bladder it becomes transitional. The submucous areolar tissue contains numerous elastic fibres. Outside this there is a highly vascular structure, in which are many large veins. Between layers of the triangular ligament, the female urethra is embraced by the fibres of the compressor urethræ muscle.

The **vessels** and **nerves** of the female urethra are very numerous, and are derived from the same sources as those of the vagina.

THE HYMEN.

The hymen is a thin fold of mucous membrane, which is situated at the vulvo-vaginal orifice, and narrows this opening so that it will usually only admit the little finger. It is generally described as forming an annular fold, which is much broader behind than in front ; but the fold is compressed from side to side, and has its free edge directed downwards so that the opening is a vertical slit bounded by lateral lips, the inner surfaces of which are in close apposition (Cullingworth). In rare cases the hymen forms a complete partition between the vagina and vulva, giving rise to the condition known as "imperforate hymen." It has been described as occasionally cribriform, and even in some cases as entirely absent. The small rounded elevations called *carunculæ myrtiformes,* found in women who have borne children, are probably the remains of the hymen. The vaginal surface of the hymen shows a few folds continuous with the rugæ of the vagina. This fact is considered by Budin to favour his view that the hymen is vaginal in its origin. Others hold that it is of vulval origin, as in various cases of absence of the vagina the hymen has been found well developed.

THE VAGINA.

The vagina is a dilatable membranous and muscular passage, extending from the vulva to the uterus, the neck of which is embraced by it. It passes with a slight curve from above downwards and forwards, usually nearly parallel with the plane of the pelvic inlet, but tending to become more horizontal with a distended bladder, and more vertical when the lower part of the rectum is loaded. The ends of the vagina are somewhat narrower than the middle part ; the lower end, which is the

narrowest, is H-shaped on transverse section, the middle part is flattened from before backwards, so that its anterior and posterior walls are ordinarily in contact with each other (see fig. 272). At its upper end it is rounded, and expands to receive the vaginal part of the neck of the uterus. The vagina reaches higher up on the cervix uteri behind than in front, so that the uterus appears to be inserted into its anterior wall. The anterior wall of the vagina is about $2\frac{1}{2}$ inches (6 centimeters) in length, and the posterior $3\frac{1}{2}$ inches (8·5 centimeters). In front the vagina is in relation with the bladder and urethra, its anterior wall being connected by loose areolar tissue with the bladder, but intimately blended with the urethra. The

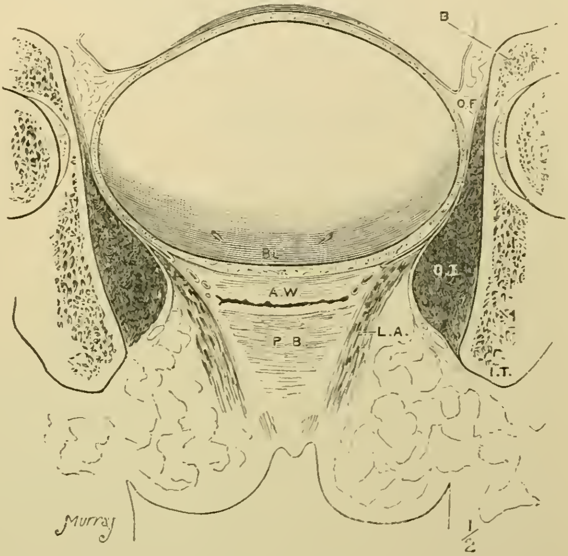


Fig. 272.—Coronal section of pelvis of female aged 54 passing through bladder, vagina, and perineal body. (J. S.)

B., brim of true pelvis: I.T., ischial tuberosity; O.I., obturator internus; O.F., obturator fascia; L.A., levator ani; P.B., perineal body; A.W., anterior vaginal wall; BL., trigone of bladder. The transverse black line below A.W. represents the cavity of the vagina.

posterior vaginal wall is usually covered in about its upper fourth by the peritoneum, and below this is loosely attached to the anterior wall of the rectum. At the sides it is enclosed between the levatores ani muscles (fig 272).

Structure. — The walls of the vagina are composed from within outwards of a mucous membrane, a muscular and a fibrous coat. They are thickest in front, in the vicinity of the urethra, which indeed may be said to be imbedded in the anterior wall of the vaginal passage; in other situations they are thinner. The vagina is firmly connected by areolar tissue to the neck of the bladder, and only loosely to the rectum and levatores ani muscles; at the upper end as just stated, for about a fourth part of its length, its posterior surface receives a covering from the peritoneum, which descends in the form of a cul-de-sac thus far between the vagina and the rectum.

Externally the vagina is covered by a coat of dense areolar tissue, and beneath this its walls are composed of unstriped muscle, which is not distinctly separable into strata, but is composed chiefly of fibres internally circular and externally longitudinal. Round the tube a layer of loose erectile tissue is found, which is most marked towards the vulva.

At its lower end, the vagina is embraced by striated muscular fibres, which constitute the *sphincter vaginæ*, already described.

On the *inner surface* of the vagina, anteriorly and posteriorly, a slightly elevated ridge extends from the lower end upwards in the middle line, forming the *columns of the vagina*, or *columnæ rugarum*. Numerous dentated transverse ridges, called *rugæ*, are also observed, particularly in persons who have not borne children, running at right angles from the columns. These columns and rugæ are most evident near the entrance of the vagina and on the anterior surface, and gradually become less marked, and disappear towards its upper end.

The mucous membrane, besides the columns and rugæ, is provided with microscopic papillæ, and is lined with a stratified scaly epithelium. Mucous glands are stated by Veith to be usually absent altogether, but one or two may occasionally be met with.

Vessels and nerves.—The vagina is largely supplied with vessels and nerves. The **arteries** are derived from branches of the internal iliac, viz. the *vaginal, internal pudic, vesical*, and *uterine*. The **veins** correspond; but they first surround the vagina with numerous branches, and form at each side a plexus named the *vaginal plexus*. The **nerves** are derived from the *hypogastric plexus* of the sympathetic, and from the *fourth sacral* and *pudic* nerves of the spinal system; the former are traceable to the erectile tissue.

THE UTERUS.

The uterus or womb (*matrix*, ὑστερον), is a hollow muscular organ with very thick walls situated in the pelvic cavity between the rectum and the urinary bladder. The Fallopian tubes, extending from each upper angle of the uterus to their ovarian opening, conduct the ovum from the ovary to the uterine cavity. In the case of pregnancy the uterus receives the ovum, retains and supports it during the development of the fœtus, and expels it at the time of parturition. During gestation the uterus undergoes a great enlargement in size and capacity, as well as important structural changes.

In the fully developed virgin condition, which is that to which the following description mainly applies, the uterus is a somewhat pear-shaped body flattened from before backwards, free above, and connected below with the vagina into which its lower extremity projects. Its average dimensions are three inches (7·5 centimeters) in length, two inches (5 centimeters) in breadth at its upper and wider part, and nearly an inch (2·5 centimeters) in thickness; it weighs from 7 to 12 drachms (33 to 41 grammes). It is usually described as possessing a fundus, body, and neck.

The **fundus** is the broad convex upper end of the body, which projects upwards from between the points of attachment of the Fallopian tubes (fig. 274). The **body** gradually narrows as it extends from the fundus to the neck; its sides are nearly straight; its anterior and posterior surfaces are both somewhat convex, but the latter more so than the former. At the points of union of the sides with the rounded superior border are two projecting angles with which the Fallopian tubes are connected, the round ligaments being attached a little before, and the ovarian ligaments behind and beneath them: these three parts are all included within the peritoneal duplicature of the broad ligaments (fig. 274). The **neck** or *cervix uteri*, narrower and more rounded than the rest of the organ, is about an inch in length; it is continuous above with the body, and becoming somewhat smaller towards its lower extremity projects into the anterior part of the upper end of the tube of the vagina, which is united all round with the substance of the uterus, but extends upwards to a greater distance behind than in front. The cervix may be divided into three parts, upper, middle, and lower, according to their relation to the vagina. The upper and middle parts lie respectively above and opposite the attachments of the vaginal walls, while the lower portion projects free towards the cavity of the vagina being entirely below the line of union of the uterine and vaginal walls. The lower end of this, the vaginal part of the cervix, has a transverse aperture by which its cavity opens into the vagina (figs. 273, 274); this is variously named *os uteri, os uteri externum*, and (from a supposed resemblance to the mouth of the tench fish) *os tincæ*. It is bounded by two thick lips, the posterior of which is the thinner and longer of the two, while the anterior, although projecting less from its vaginal attachments, is lower in position, so that when the tube is closed both lips come into contact with the posterior wall of the vagina. These borders or lips are smooth

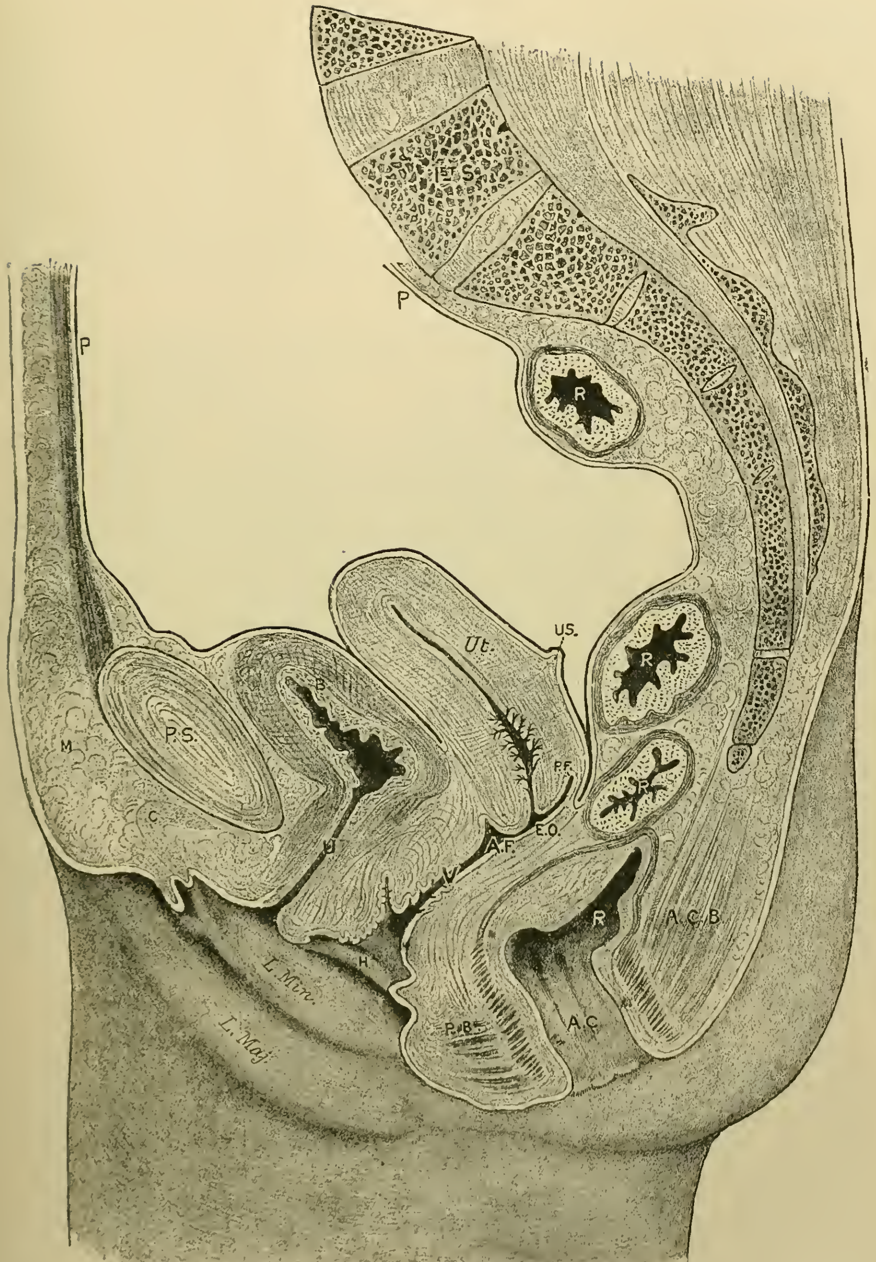


Fig. 273.—Median section of the pelvis of a female aged about 30 years. (J. S.) ¾

1st s., body of 1st sacral vertebra; P.S., pubic symphysis; B., bladder; U., urethra; Ut., uterus; E.O., external os uteri; U.S., utero-sacral ligaments which are united with one another on posterior aspect of uterus; V., vagina; A.F., anterior vaginal fornix; P.F., posterior vaginal fornix; H., hymen; R., rectum; A.C., anal canal; L.Min., labium minus; L.Maj., labium majus; C., clitoris; M., fat of mons Veneris; P., peritoneum; P.B., perineal body; A.C.B., ano-coccygeal body.

This section was made after hardening the body by the injection of a 1 p. c. solution of chromic acid, and the distension of the abdominal vessels with this fluid probably depressed somewhat the pelvic viscera.

in the nullipara, but after parturition they frequently become irregular, and are sometimes fissured or cleft.

The peritoneum covers the upper end or fundus of the uterus, and also the anterior surface of the body. Anteriorly, at about the union of the body with the cervix it is reflected on to the bladder, forming the *utero-vesical pouch.* The anterior aspect of the cervix is thus uncovered by peritoneum, and it is connected with the bladder by loose cellular tissue. The posterior surface of the body and upper part of the cervix is covered by peritoneum, and below this level the membrane passes on to the posterior wall of the vagina, which thus separates the lower part of the back of the cervix from the peritoneum. From the sides of the uterus the peritoneum is prolonged outwards in the form of duplicatures named the broad ligaments.

Cavity of the uterus.—The walls of the uterus are of great thickness, and the cavity is thus proportionately much reduced in size. The part within the body is

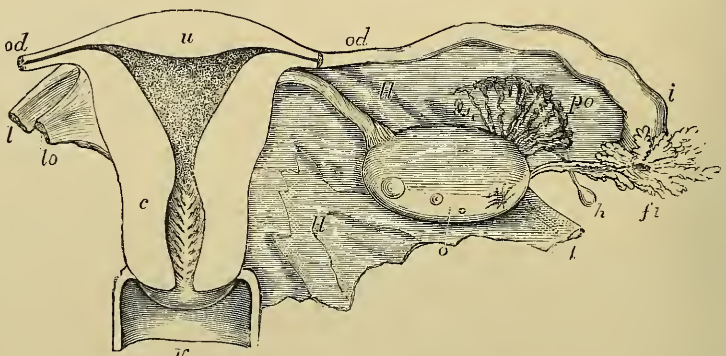


Fig. 274.—Diagrammatic view of the uterus and its appendages, as seen from behind. (A. T.) $\frac{2}{3}$.

The uterus and upper part of the vagina have been laid open by removing the posterior wall; on the left side the Fallopian tube, round ligament, and ovarian ligament have been cut short, and the broad ligament removed; *u*, the fundus of the uterus; *c*, the cervix opposite the os internum; the triangular shape of the uterine cavity is shown, and the dilatation of the cervical cavity with the rugæ termed arbor vitæ; *v*, upper part of the vagina; *od*, Fallopian tube or oviduct; *l*, round ligament; *lo*, ligament of the ovary; *o*, ovary (here represented with its long axis horizontal although in the natural position within the body it is oblique or nearly vertical); *i*, wide outer part of the right Fallopian tube; *f i*, its fimbriated extremity; *po*, parovarium; *h*, one of the hydatids frequently found connected with the broad ligament.

triangular (fig. 274), and flattened from before backwards, so that its anterior and posterior walls touch each other (fig. 273). The base of the triangle is directed upwards, and is convex towards the interior of the uterus. The cavity, narrowing gradually, is prolonged into its two superior angles, at each of which it leads by a minute foramen into the narrow canal of the Fallopian tube. At the junction of the body and the neck, the cavity is slightly constricted, and thus forms what is sometimes named the *internal orifice* (*os uteri internum, isthmus vel ostium uteri*); this opening is often smaller than the os externum, and is of a circular form. That portion of the cavity which is within the neck is tubular and slightly flattened before and behind; it is somewhat dilated in the middle, and opens inferiorly into the vagina by the os uteri externum. Its inner surface is marked by two longitudinal ridges or columns, which run, one on the anterior, the other on the posterior wall, and from both of which rugæ are directed obliquely upwards on each side, so as to present an appearance which has been named *arbor vitæ uterina*, or *palmæ plicatæ* (fig. 274): this structure is most strongly marked anteriorly.

Position of the uterus.—The question as to the normal position of the uterus is one that has given rise to much controversy, and regarding which very

contradictory statements have been made. The uterus does not occupy any definite fixed position, but possesses a considerable range of mobility, the chief factors that influence its position being the intra-abdominal pressure, and the condition of the bladder and rectum. In the nullipara, with the bladder empty, the whole uterus is inclined forwards (anteverted), and the body is also bent upon the cervix (anteflexed), the body of the uterus lying upon the bladder. As the bladder becomes filled the body and fundus are pushed upwards and backwards, until, if the bladder be fully distended and the rectum empty, the upper part of the uterus may come to lie near the sacrum, and the long axis of the organ be directed from above downwards and forwards nearly parallel with that of the vagina. As a rule there are no intestines in the pouch between the uterus and the bladder, these two organs lying in close

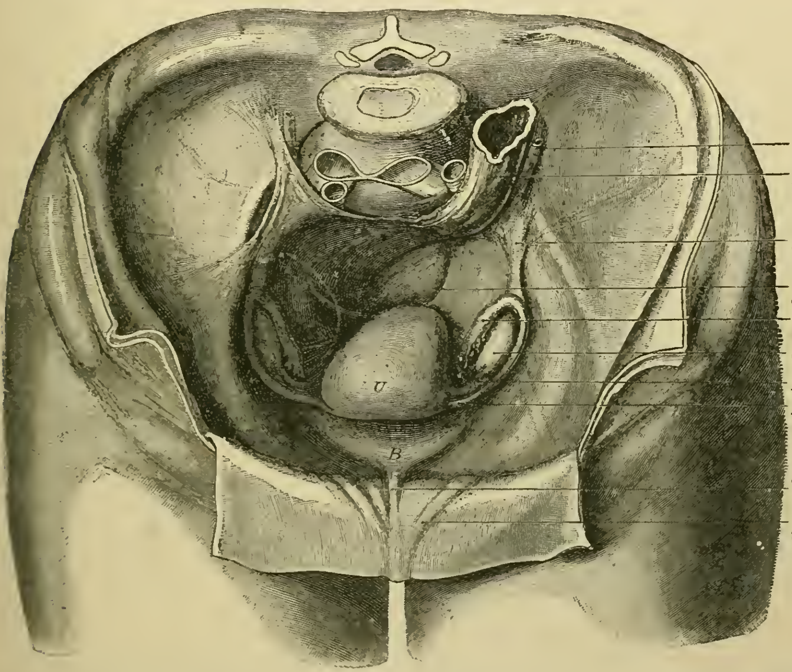


Fig. 275.—View of the female pelvic viscera from above. (v. Bardeleben and Haeckel.) *U*, uterus ; *B*, bladder.

contact. Occasionally however, especially in women who have borne children, the upper part of the uterus points somewhat backwards, and the utero-vesical pouch is occupied by some portion of the intestine. The uterus generally deviates to one or other side, this lateral displacement usually affecting the body more than the cervix.

Ligaments of the uterus.—The reflection of the peritoneum from the uterus to the bladder is called the *utero-vesical* fold or sometimes the *anterior ligament of the uterus.* Posteriorly, as we have already seen, the peritoneum passes from the uterus on to the upper part of the vagina before being reflected backwards to the rectum, thus forming a *recto-vaginal* ligament. The peritoneal recess situated in front of the rectum, and behind the cervix of the uterus and the upper part of the vagina is usually termed the *pouch of Douglas.* This pouch is bounded on each side by a semilunar fold of the peritoneum, which joins the upper part of the cervix uteri in front and extends backwards on the side of the rectum towards the sacrum. This fold contains a variable amount of fibrous tissue and some non-striped muscular fibres forming the *utero-sacral ligament.*

The **broad ligaments** (fig. 274) are formed on each side by a fold or double layer of the peritoneum, which is directed laterally from the anterior and posterior surfaces of the uterus, to be connected with the sides of the pelvic cavity. Between the two layers of the serous membrane are placed the Fallopian tube, the round ligament of the uterus, the ovary and its ligament, the parovarium, and numerous blood-vessels, lymphatics, and nerves with fibres spreading from the superficial muscular layer of the uterus. The Fallopian tube is situated at the upper border of a special fold of the broad ligament sometimes termed the *meso-salpinx.* This fold is attached to the main part of the broad ligament close to the ovary and its ligament. It is narrow internally, but broadens as it passes outwards. The parovarium is enclosed within its two layers between the ovary and the outer part of the Fallopian tube. This fold is thin, its serous layers being separated by only a small quantity of areolar and muscular tissue. The ovary and its ligament are situated in a special extension from the posterior part of the broad ligament. The *ligament of the ovary* is merely a dense fibro-areolar cord, containing some uterine muscular fibres, and measuring from an inch to an inch-and-a-half in length, which extends from the lower end of the ovary to the upper angle of the uterus, which it joins immediately below and behind the point of attachment of the Fallopian tube.

The **round ligaments** are two flat, cord-like bundles of fibres, about four or five inches in length, attached to the upper angles of the uterus, one on either side, immediately in front of the Fallopian tube. As each ligament proceeds upwards, outwards, and forwards towards the internal abdominal ring it raises the anterior layer of the broad ligament into a more or less prominent fold. After having passed, like the spermatic cord in the male, through the inguinal canal, it reaches the fore part of the pubic symphysis, where its fibres expand and become united with the substance of the mons Veneris. Besides areolar tissue and vessels, the round ligaments contain, chiefly in their inner third, plain muscular fibres, which are prolonged into them from the outer muscular layer of the uterine wall. Each ligament also receives a covering from the peritoneum, which, in the young subject, projects in the form of a tubular process for some distance into the inguinal canal ; this, which resembles the processus vaginalis originally existing in the same situation in the male, is named the *canal of Nuck ;* it is generally obliterated in the adult, but is sometimes found even in advanced life.

STRUCTURE OF THE UTERUS.

The walls of the uterus consist of an outer serous covering, an inner mucous membrane, and thick intermediate muscular substance. The serous covering or peritoneal layer has been already referred to.

The thick middle part of the wall of the uterus is of firm consistence : being mainly composed of plain muscular fibres of small size, 0·23 mm. in length, in the unimpregnated uterus, but greatly enlarged in the gravid state. These fibres interlace closely with each other, but are disposed in bundles and layers, and are intermixed with areolar tissue, a large number of blood-vessels and lymphatics, and some nerves. The areolar tissue is more abundant near the outer surface. The arrangement of the muscular fibres is best studied in the uterus at the full period of gestation, in which the bundles become augmented in size. They may be referred to three sets of which the two more external may be regarded as corresponding with the muscular coat of other hollow viscera, whereas the internal is an immensely hypertrophied *muscularis mucosæ*, and will accordingly be described with the mucous membrane.

Muscular coat.—The *external layer* of the muscular coat forms a thin superficial sheet immediately beneath the peritoneum, and incomplete strata situated more deeply. A large share of these fibres, beginning as longitudinal bands at the

cervix, arch transversely and obliquely over the fundus and adjoining part of the body of the organ, and pass on each side into the broad ligament. Of these some converge at either side towards the commencement of the round ligaments, along which they are in part prolonged to the groin ; others pass off to the Fallopian tubes, and strong transverse bands from the anterior and posterior surfaces are extended into the ovarian ligaments. Other fibres run back from the cervix uteri beneath the utero-sacral folds of the peritoneum. The *inner layer* of the muscular coat, which is also thin, is composed of fibres which are found chiefly on the back of the uterus, and stretch over the fundus and towards the sides, running somewhat irregularly between the ramifications of the blood-vessels. The muscular coat proper seldom exceeds 6 mm. in thickness altogether, but it is not easy to assign its limits exactly, for there is little or no submucous areolar tissue forming a distinct coat as in most of the hollow viscera. But the place of ramification of the blood-vessels before they pass into the mucous membrane serves to determine the boundary between the muscular layer of the mucous membrane and the muscular coat proper (J. Williams).

Mucous membrane.—The mucous membrane of the uterus is characterized by the enormous hypertrophy of the muscular layer proper to it—the muscularis mucosæ ; indeed it is this which forms the greater part of the thickness of the uterine wall. The presence of this mass of plain muscular tissue in it confers a distinct character on the outer part of the membrane, so that in sections it is distinctly differentiated from the inner part or corium.

Muscularis mucosæ.—This consists of bands of fibres which are disposed with comparative regularity in its upper part, being arranged there in numerous concentric rings round the openings of the two Fallopian tubes, the widest circles of the two series meeting from opposite sides in the middle of the uterus. In the lower part of the body, and in the cervix the internal fibres run more transversely. They form the so-called sphincters of the os internum and os externum. At the neck, however, there are also longitudinal fibres within the transverse.

Corium.—As regards its inner part or corium the mucous membrane lining the cavity of the body differs greatly from that of the cervix, a distinct line of demarcation separating the two parts at the isthmus.

The *mucous membrane of the body* of the uterus is smooth, except during the menstrual period, and in the unimpregnated state is entirely devoid of ridges ; it is of a peculiar soft spongy consistence, and of a dull, reddish colour.

Under the microscope it appears composed in great measure of small, rounded, spindle-shaped, or irregular cells imbedded in a homogeneous ground-substance and with but few connective tissue fibres apparent (fig. 276). According to Leopold there are, however, numerous fibres, and they form a spongework with lymphatic spaces in the meshes. The inner surface is everywhere covered by columnar ciliated epithelium, and is beset, but somewhat sparingly, by the orifices of the uterine glands (fig. 277). These, which were discovered by Sharpey, are simple tubes bounded by a basement membrane and lined with ciliated columnar cells like those covering the inner surface. They pass usually obliquely and often with an irregular or convoluted course into the deeper part of the mucous membrane, and there terminate by blind, sometimes forked extremities, which are situated amongst the bundles of the muscularis mucosæ. Towards their extremities the uterine glands are entirely filled by cells (fig. 277, *b'*), but in the greater part of their extent they have a distinct lumen.

The *mucous membrane of the cervix* is much firmer and more fibrous than that of the body. Between the rugæ of the *arbor vitæ* there are numerous saccular and tubular glands. In the lower part of the cervix the mucous membrane is beset with vascular papillæ, and the epithelium is stratified, but in the upper half or more the

epithelium is columnar and ciliated like that of the body. The glands, which are short, with a large lumen, are everywhere lined with columnar ciliated epithelium, even where the epithelium of the surface is stratified. Besides the follicular glands there are almost constantly to be seen the so-called *ovula Nabothi*, clear yellowish vesicles of variable size, but visible to the naked eye, embedded in the membrane. These probably arise from closed and distended follicles; but their exact nature is still doubtful.

During pregnancy the mucous glands of the cervix secrete a considerable quantity of tenacious mucus, which effectually closes the passage downwards from the uterine cavity.

The surface of the os uteri is covered, like the vaginal portion, with stratified epithelium, which conceals the vascular papillæ. It is destitute of glands.

The arrangement of the muscular fibres both of the muscular coat proper and of the muscularis mucosæ is more regular and more easily made out in the uterus of the lower

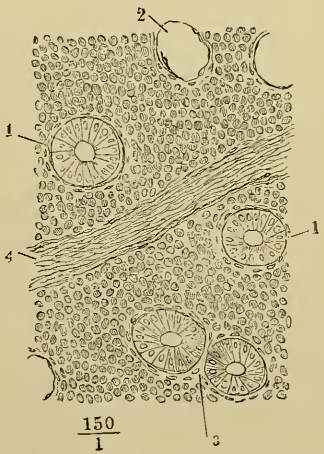


Fig. 276.—Section of the uterine mucous membrane parallel to the surface (Henle). $\frac{150}{1}$.
1, 2, 3, glands (the epithelium has fallen out from 2); 4, a blood vessel.

Fig. 277.—Section of the mucous membrane of the human uterus from near the fundus (adapted by J. C. Ewart from a figure from J. Williams).

a, epithelium of inner suface; *b*, *b*, uterine glands; *c*, interglandular connective tissue; *d*, part of the muscularis mucosæ with the ends of the glands, some of which, *b′*, are entirely filled by epithelium cells. This specimen was prepared from the uterus of a young woman who was accidentally killed three or four days before the expected appearance of the menstrual flow, and the mucous membrane and glands are therefore in the hypertrophied condition which precedes menstruation.

mammals (below Primates), which possess a bi-cornel uterus consisting of two long tubular portions, which unite below before opening into the vagina. A section across one of the horns of such a uterus is represented in fig. 278, from which it will be seen that the fibres of the muscularis mucosæ (*m.m.*) run almost entirely in a transverse or circular direction, and are imperfectly separated by an areolar layer (*a.*) containing the large bloodvessels of the organ from the inner thin layer of circular fibres of the muscular tunic proper (*c.m.*). Outside these are seen the stout bundles of the outer or longitudinal muscular layer (*l.m.*), and most externally is the peritoneal or serous coat (*s.*).

Periodic structural changes in the uterus.—The changes which accompany menstruation and gestation may be shortly indicated here.

At each successive recurrence of *menstruation* a complete removal of the superficial part of the mucous membrane takes place by a process of softening and molecular disintegration which commences, along with the menstrual discharge, close to the cervix, or at the os internum, and advances progressively towards the fundus during the remaining days of the flow of blood (J. Williams). Previous to this change, there is a greatly increased general vascularity of the parts, and the mucous membrane becomes very much thicker. The process of disintegration reaches as far as the inner fibres of the muscularis mucosæ ; and the hæmorrhage is the direct result of the destruction and open condition of the small vessels.

The process of restoration of the uterine membrane, which begins even before the cessation of the menstrual flow, proceeds in the same order, from the lower end upwards to the fundus, and consists in a very rapid proliferation of the cells and nuclei which occupy the interstices of the inner muscular fibres, and among which are embedded the deepest parts of the uterine glands The whole of the destroyed epithelial structure both of the glands and of the general surface is renewed from the epithelium of these parts of the glands. The epithelial regeneration is very rapid, and the inner surface is already covered again with epithelium very shortly after the menstrual flow has ceased, but the original thickness of the mucous membrane is not at once attained, the growth in thickness progressing gradually up to the time of the next menstruation, and with it the growth in length and the intricacy of the uterine glands. The lining membrane of the cervix does not participate in the changes referred to.

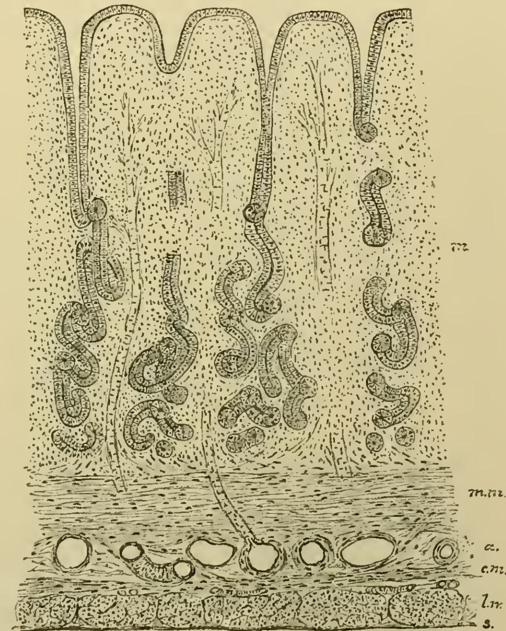


Fig. 278. — Transverse vertical section of the wall of one of the cornua uteri of the rabbit. (E. A. S.)

s, serous layer ; *l. m.*, longitudinal fibres of the muscular coat ; *c. m.*, circular fibres of the same ; *a*, areolar tissue with large blood-vessels ; *m. m.*, muscularis mucosæ ; *m.*, mucosa, with coiled glands.

In *gestation* more extensive alterations ensue. The weight of the organ increases from about one ounce to a pound-and-a-half or even three pounds. Its colour becomes darker, its tissue less dense and its muscular bundles more evident. A very great increase takes place in the muscular tissue, this increase being mainly the result of the enlargement of the already existing elements, the cells becoming enlarged to the extent of from seven to eleven times in length, and from two to five times in breadth (Kölliker). A formation of new cells is also said to occur mainly in the innermost layers (but whether by proliferation of pre-existing cells or otherwise is not stated), and to continue until the sixth month of pregnancy, when it ceases. The round ligaments become enlarged, and their muscular structure more marked ; the broad ligaments are encroached upon by the intrusion of the growing

uterus between their layers. The mucous membrane and the glands of the body of the uterus at first undergo an enlargement very similar to that which precedes menstruation, and they subsequently become the seat of peculiar changes, more particularly described under Development (Vol. I., Part 1). The blood-vessels and lymphatics are greatly enlarged, and it is observed that the arteries become exceedingly tortuous as they ramify upon the organ. The nerves also undergo considerable increase in size.

After parturition, the uterus gradually but rapidly diminishes till it nearly regains the size and structure of the unimpregnated condition. During this change the enlarged muscular fibres undergo fatty degeneration and are said to become subsequently absorbed, while a new set of fibre-cells is developed. After the first pregnancy,

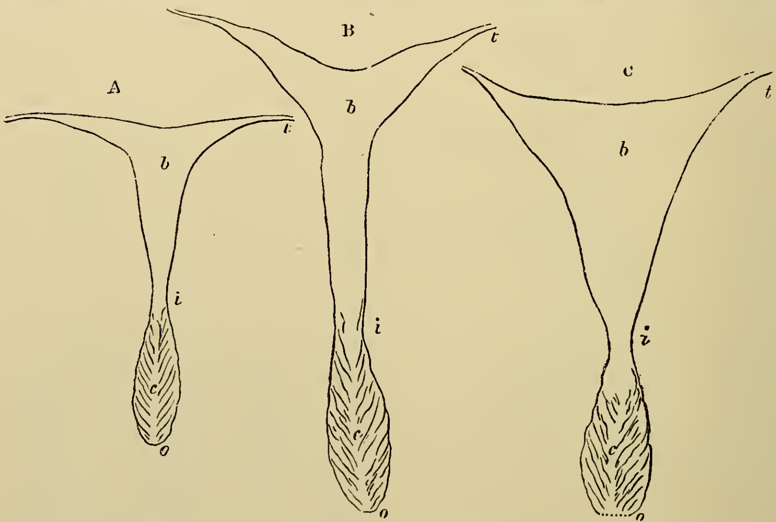


Fig. 279.—Outlines of moulds of the uterine cavity in different states (after F. Guyon). Natural size.

A, in a virgin of 17 years of age ; B, in a woman of 42 years who had not borne children ; C, in a woman of 35 years who had borne children ; *b*, cavity of the body ; *c*, that of the cervix ; *i*, the isthmus or os internum ; *o*, os externum ; *t*, passage of the upper angle into the Fallopian tube.

however, the organ never regains its original virginal character. In those who have had children its weight usually remains from two to three ounces (102-117 grammes, Vierordt) ; its cavity is larger (fig. 279, C) ; the os externum is wider and more rounded, and its margins often puckered or fissured ; the arteries remain much more tortuous, and its muscular fibres and layers more defined than in the virgin.

Peculiarities according to age.—In the newly-born infant the neck of the uterus is larger than the body, and also much firmer. There is no fundus, the upper end of the uterus not forming a convex prominence between the attachments of the Fallopian tubes. The cavity is narrow, there is no distinct internal os and it tapers above on both sides so as to present an approach to the two-horned form prevalent in animals. The arbor vitæ is very distinct and reaches to the highest point of the cavity. At this period the uterus is usually from an inch to an inch-and-a-quarter in length. It grows but slightly from birth until near puberty, at which period it undergoes a rapid and marked increase in size. This growth is especially marked in the body, which at the same time acquires a firmer consistence, while its mucous membrane becomes smooth. The cavity remains comparatively narrow in all women who have borne no children (fig. 279, B), while in those who have been pregnant it is widely triangular (C). In old age the uterus atrophies : it becomes paler in colour and harder in texture, and its external os frequently becomes diminished in size.

Varieties.—The uterus is subject to numerous congenital defects or malformations especially in connection with abnormal conditions of the other genital organs. Amongst

those involving the uterus may be mentioned its more or less complete absence, the occurrence of one or two horns at its upper part, and the presence of two distinct cavities. Such cases are obviously due to an imperfect development of one or both Müllerian ducts or their incomplete fusion (see Development, Vol. I., Pt. 1). Occasionally the uterus retains its infantile condition after puberty.

Vessels and nerves.—The **arteries** of the uterus are four in number, viz., the right and left *ovarian* (which correspond to the spermatic of the male) and the *uterine*. Their origin, as well as the mode in which they reach the uterus and ovaries, has been described in Vol. II., Pt. 2. They are remarkable for their frequent anastomoses, and also for their singularly tortuous course. After passing a short distance into the thickness of the uterine wall they divide into branches, which penetrate the muscular tissue of the mucous membrane, supplying it with capillaries, and then pass towards the inner portion of the membrane and open into a network of large capillaries which pervades the tissue in that situation, and is especially developed near the surface and around the glands. In the cervix, however, and especially in the vaginal portion, the arteries, which in this situation possess walls of considerable thickness, after entering the mucous membrane, divide into a number of small branches which pass directly towards the surface and open into the capillary network there present, from which loops pass into the papillæ. The **veins** correspond with the arteries; they are very large, and form plexuses of sinus-like vessels, with thin walls in immediate contact with the uterine tissue. The **lymphatics** commence according to Leopold as cleft-like spaces in the mucous membrane, and there are also well-marked lymphatic vessels extending as a plexus through the whole thickness of the membrane (Hoggan). These open into plexuses of vessels in the muscularis mucosæ and muscular coat proper; and these again are in communication with valved vessels beneath and in the serous covering.

The **nerves** are derived from the *inferior hypogastric plexuses*, the *spermatic plexuses*, and the *third* and *fourth sacral* nerves. They consist of both medullated and non-medullated fibres, and in animals small ganglia have been observed in the submucous tissue, connected with the non-medullated fibres.

THE FALLOPIAN TUBES.

The two Fallopian tubes may be considered as ducts of the ovaries (oviducts) since they serve to convey the ova from these glands into the uterus. They differ, however, from the ducts of all the other glands in the body in being detached from the organs whose secretions they convey. They are enclosed in the free margin of the broad ligaments in the whole of their extent, except at their inner ends, where they pierce the uterine wall. Traced from the uterus, to the superior angles of which they are attached, they are found to pass almost horizontally outwards, for a distance of from half an inch to an inch, until they reach the side walls of the pelvis, against which they ascend, frequently in a tortuous manner, in front of their corresponding ovaries and then arch backwards above these glands and internal to their suspensory ligaments (fig. 280). Finally they turn downwards so that the fimbriæ are opposite the inner surfaces and posterior borders of the ovaries. Some convolutions of the small intestine are often situated above and internal to the right Fallopian tube, while the sigmoid loop of the large intestine may have a similar relation to the left one. The average length of the tubes is from four to five inches (120 mm.), and, as a rule, the right one is a little longer than the left.

Each tube may be divided into an *isthmus*, an *ampulla*, a *neck*, and a *fimbriated extremity*. The *isthmus* corresponds to about the inner third of the tube, it is straight, round and cord-like, and has a diameter of 2 mm. to 3 mm. Its lumen communicates with the uterine cavity by an orifice which will barely admit a hog's bristle. From this opening its cavity enlarges as it passes outwards but only very

gradually. The *ampulla* extends from the isthmus to the neck, and forms rather more than one half of the total length of the tube. It differs from the isthmus in its larger size, in being less firm to the touch and by its tortuous course. This part of the tube increases in size from the isthmus to the neck, and its average diameter is 6 mm. to 8 mm., while in many cases it will admit, in the greater part of its length, a No. 6 to No. 8 catheter. Ballantyne and Williams found that the orifice at the *neck* of the tube, or *ostium abdominale,* was physiologically closed in tubes removed during life, while in specimens obtained from the post mortem room it was somewhat gaping. When moderately distended it has a diameter of

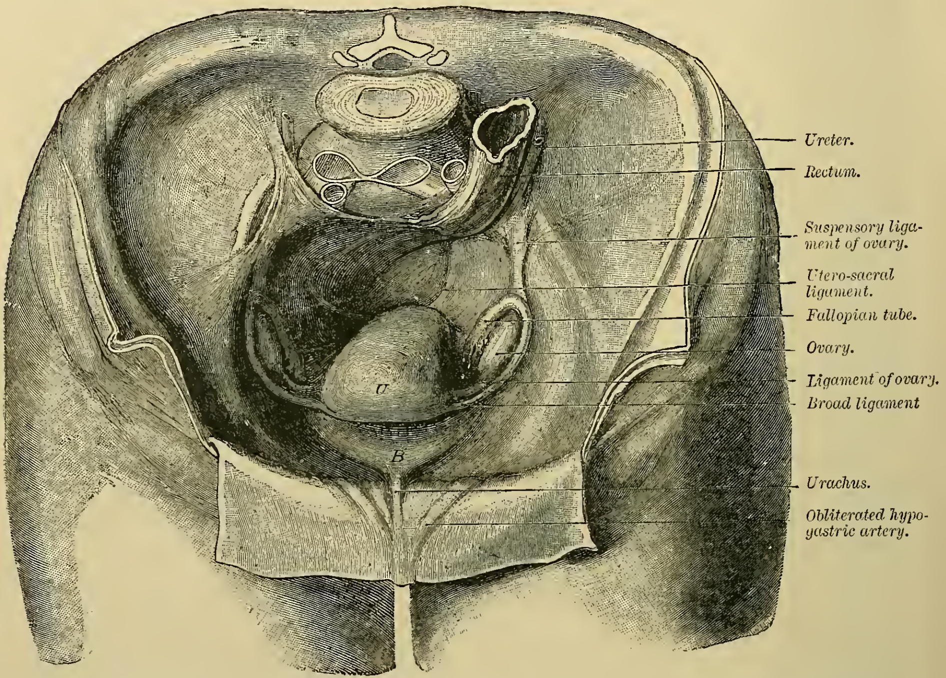


Fig. 280.—Pelvic organs of the female, viewed from above. (v. Bardeleben & Haeckel.) *U*, uterus ; *B*, bladder.

3 or 4 mm. The ovarian end of the tube expands in a trumpet-shaped manner from the neck to enclose a space called the *infundibulum* or *pavilion*, and is then prolonged into a number of irregular processes called *fimbriæ,* hence the term *fimbriated extremity.* From its irregular torn appearance it was named by the ancient anatomists *morsus diaboli.* The fimbriæ vary considerably in number, size, and complexity. The larger ones have numerous smaller processes attached to their edges, and their inner surfaces present folds continuous with those lining the pavilion. One of the fimbriæ, which is longer than the others, is attached to the upper end of the ovary. This, the *ovarian fimbria,* has a longitudinal groove leading from the pavilion to the ovary, and bounded at its sides by secondary fimbriæ. In some cases this fimbria does not reach the ovary, but is attached to it by a ligament.

Peculiarities according to age.—In the new-born child the Fallopian tubes are not situated entirely in the cavity of the true pelvis, their outer ends lying in the iliac fossæ. The ampullary part of the tube shows one to three spiral twists, and the edges of the ovarian fimbria are not fringed. In old age the tubes tend to become narrower and straighter, and their muscular coat atrophies.

Varieties.—A pedunculated cyst, known as the *hydatid of Morgagni*, apparently peritoneal in origin, is frequently found attached to one of the fimbriæ or to the tube itself. A second smaller fimbriated opening not unfrequently occurs at a short distance from the main one. Congenital absence of a part or the whole of a tube occasionally occurs.

Structure.—Beneath the external or peritoneal coat the walls of the tube contain, besides areolar tissue, plain muscular fibres, arranged in an external longitudinal and an internal circular layer. The submucous tissue contains, like that of the uterus, multipolar ganglion cells. The mucous membrane lining the tubes is thrown into longitudinal plicæ, which are broad and numerous in the wider part of the tube, and in the narrower part are broken up into very numerous arborescent processes: it is continuous, on the one hand, with the lining membrane of the

Fig. 281.—Section of the isthmus of the Fallopian tube; human. (E.A.S.)

uterus, and at the other end of the tube with the peritoneum; presenting an example of the direct continuity of a mucous and serous membrane, and making the peritoneal cavity in the female an exception to the ordinary rule of serous cavities, *i.e.*, of being perfectly closed to the exterior. The epithelium in the interior of the Fallopian tube is, like that of the uterus, columnar and ciliated; the inner surface of the fimbriæ is also provided with cilia. On their outer or serous surface it passes into the pavement epithelium of the peritoneal membrane. It does not appear that there are glands, as was at one time supposed, in the mucous membrane lining the Fallopian tubes, although the appearances of the folds of mucous membrane may simulate tubular glands (fig. 281).

THE OVARIES.

The ovaries are two somewhat flattened oval bodies, which are placed one on each side of the pelvis, and connected with the posterior layer of the broad ligament of the uterus. The weight of each is about 100 grains (7 grammes on the average according to Puech, but varying from 5·25 to 10 grammes), and they usually measure about one inch and a half in length (36 mm.), three quarters of an inch in breadth (18 mm.), and nearly half an inch (12 mm.) in thickness, but their size is variable.[1] The exact position of the ovary is by no means uniform, and opinions are

[1] Krause gives rather larger dimensions for the virgin (viz.: length, 41-52 mm.; breadth, 20-27 mm.; thickness, 10-11 mm.; volume, 4-5 c.c.) than for women of 35 to 40 who have borne children (length, 27-41 mm.; breadth, 14-16 mm.; thickness, 7-9 mm.; volume, 2-5 c.c.).

divided as to the condition which is to be regarded as normal. According to His, Waldeyer, and the majority of recent observers, the ovary in the adult nullipara is placed against the side wall of the pelvis with its long axis vertical, in the erect position of the body. Kölliker, however, describes it as lying obliquely in the pelvis with its long axis parallel with the external iliac vessels, and Hasse, while admitting that the ovary may be considered as normally occupying the position described by His, believes that it is frequently drawn towards the uterus by the plain muscular fibres contained in the broad ligament, so that its long axis is then directed obliquely downwards and inwards. Adopting the account given by His as representing the usual position of the ovary, we may describe it as presenting two surfaces, a *mesial* and a *lateral*, two borders, an *anterior* and a *posterior*, and two extremities, an *upper* and a *lower*. The **mesial surface** is free and covered to a variable extent by the fimbriated end of the Fallopian tube and the adjacent portion of the meso-salpinx. Some convolutions of the jejuno-ileum are often found on the inner side of the right ovary, and the sigmoid loop of the large intestine may have a similar relation to the left ovary. The **lateral surface** is also free and lies against a more or less distinct peritoneal depression on the side wall of the pelvis termed the *fossa ovarii*. This depression is generally situated a little below the level of the external iliac vessels, and is often bounded below and behind by the ureter. The **posterior border** is free, convex, and turned somewhat inwards towards the rectum. Like the mesial surface it is covered partially by the fimbriated end of the Fallopian tube. The **anterior border** is straighter than the posterior, it gives attachment to the broad ligament between the two layers of which is the *hilum*, where the bloodvessels and nerves enter the ovary. The Fallopian tube ascends in front of this border. To its upper extremity is attached the ovarian fimbria of the Fallopian tube, and also a peritoneal fold, termed the *ligamentum suspensorium ovarii* or *ligamentum infundibulo-pelvicum*, which passes downwards from the brim of the pelvis and contains the ovarian vessels and nerves. The Fallopian tube bends backwards at the upper end of the ovary. The lower end of the ovary is generally narrower than the upper, and is attached to the uterus by the ligament of the ovary. This extremity does not normally reach the floor of the pelvis, so that the ovary is suspended against the side wall of the pelvis.

Peculiarities according to age.—In the young fœtus the ovary lies in front of the psoas muscle near the kidney and having the Fallopian tube on its outer side. From this position it gradually passes downwards and inwards, so that at birth it lies at the brim of the pelvis with its lower and inner end projecting slightly into the pelvis, and its upper and outer part in the iliac fossa. During fœtal life the ovary is long and narrow, but soon after birth it becomes more oval in form. Until puberty its surface is smooth, but after the process of ovulation is fully established it tends to become uneven. This is due to the laceration of the surface by the rupture of the Graafian follicles and the cicatrizations that occur in connection with the closure of the openings. In old age the ovary undergoes atrophy, becoming more fibrous and less vascular.

Varieties.—The above description of the position and relations of the ovaries is based upon the examination of adult nulliparæ, with the bladder empty and the uterus anteflexed and anteverted. The ovaries, however, are not firmly fixed in any one place, and even in the same individual their position is liable to vary according to the condition of the other pelvic organs. Thus, if the uterus be moved upwards and backwards, by distention of the bladder or other causes, the ovaries will be displaced backwards towards the sacrum. His found that in cases of lateral deviation of the uterus the ovary on the side towards which the uterus lies is vertical, while the lower end of the opposite ovary is drawn towards the median plane by the ligament of the ovary, so that its long axis becomes oblique. Waldeyer, however, has recorded a case in which the ovary on the side opposite to the uterine deviation maintained its vertical position against the side wall of the pelvis, apparently on account of the ligament of the ovary being longer than usual on that side. As a rule the ovary on the side towards which the uterus is displaced is distinctly higher than the one on the opposite side. Thus in a specimen of Waldeyer's, the one ovary had its upper end 1 c.m. below the level of the external iliac vein, and the other ovary reached as high as the upper border of the corresponding vein.

Waldeyer states that he has not seen any cases, such as Hasse describes, where a normal ovary lies in contact with the uterus.

Absence of one or both ovaries is extremely rare. Occasionally the ovary retains its infantile form until adult life. It is very uncommon to find it remaining in its primitive position near the kidney, but sometimes in place of descending into the pelvis it takes a similar course to that of the testicle, passing into the inguinal canal and even through the external abdominal ring to the labium majus. When enlarged it frequently becomes prolapsed, passing downwards and inwards behind the uterus, so that when both ovaries are enlarged they may meet near the median plane.

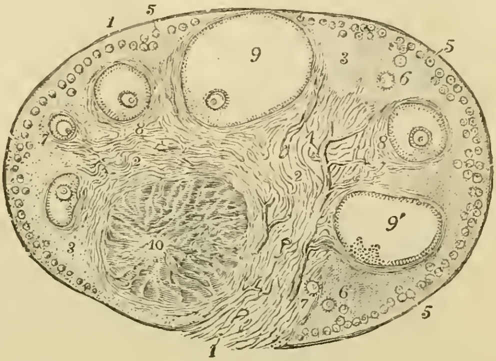


Fig. 282.—Section of the ovary of the cat. (Schrön.) $\frac{6}{1}$

1, outer covering and free border of the ovary; 1′, attached border; 2, the central ovarian stroma, presenting a fibrous and vascular structure; 3, peripheral stroma; 4, blood-vessels; 5, Graafian follicles in their earliest stages lying near the surface; 6, 7, 8, more advanced follicles which are imbedded more deeply in the stroma; 9, an almost mature follicle containing the ovum in its deepest part; 9′, a follicle from which the ovum has accidentally escaped; 10, corpus luteum.

Structure of the Ovary.

The ovary consists of a stroma, in which are embedded Graafian follicles containing ova. The stroma is composed of a peculiar connective tissue with blood-vessels, nerves, and plain muscular fibres, and it has an outer epithelial covering.

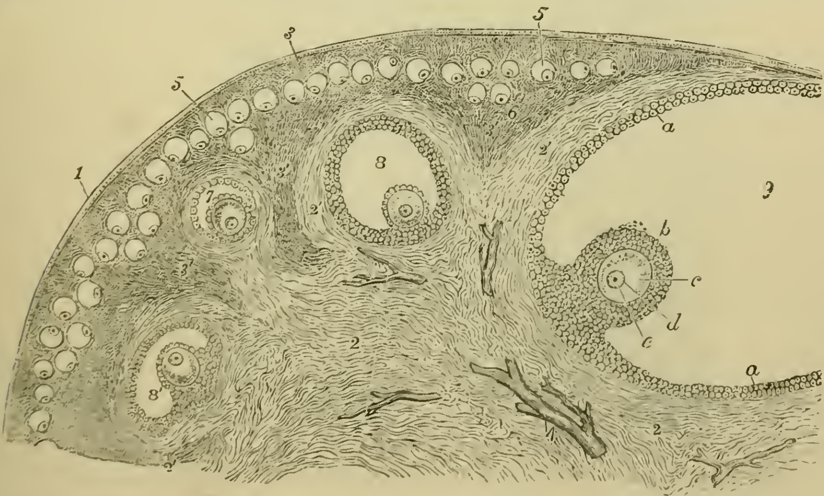


Fig. 283.—Portion of the section of the prepared cat's ovary, represented in the preceding figure, more highly magnified. (Schrön.)

1, epithelium and outer covering of the ovary; 2, fibrous stroma; 3, 3′, less fibrous, more superficial stroma; 4, blood-vessels; 5, small Graafian follicles near the surface; 6, one or two more deeply placed; 7, one farther developed, enclosed by a prolongation of the fibrous stroma; 8, a follicle farther advanced; 8′, another which is irregularly compressed; 9, part of the largest follicle; *a*, tunica granulosa; *b*, discus proligerus; *c*, ovum; *d*, germinal vesicle; *e*, germinal spot.

Epithelium and stroma.—The external surface of the ovary is of a whitish colour, and in early life is comparatively smooth and even; but in later life becomes more uneven and is marked by pits and scars. It is covered by an epi-

thelium which differs from that of the peritoneum in being composed of pyriform or columnar cells ; and the surface has a dull appearance as compared with the shining smoothness of the serous membrane. A distinct line of demarcation exists around the attachment of the ovary, where the two kinds of epithelium pass into each other (Waldeyer). This ovarian epithelium is the remains of the *germinal epithelium* from which both the ova and the other cells within the Graafian follicles have been developed in the embryo. Here and there are occasionally to be seen amongst the ordinary epithelium-cells, others which are much enlarged and of a spherical form. These are primitive ova, similar to those from which the permanent ova are formed

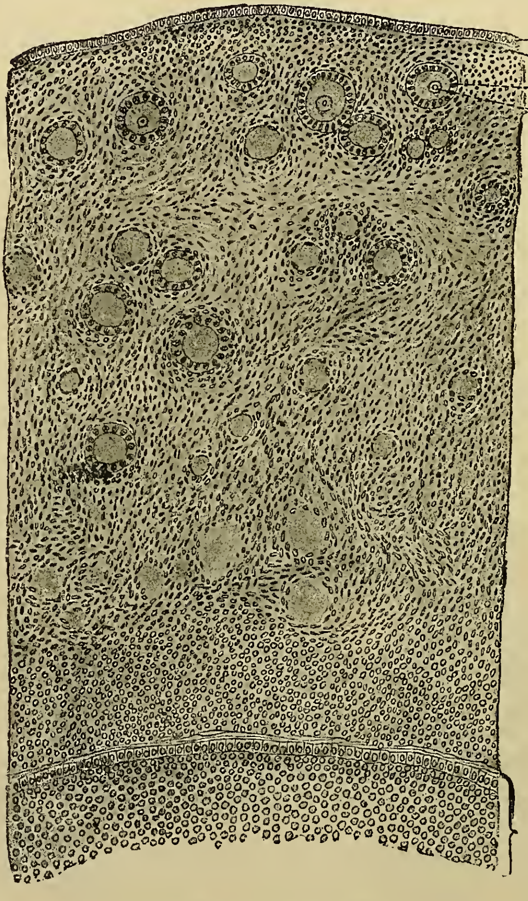


Fig. 284.—Section of part of the ovary of a young girl. (v. Böhm and Davidoff.) $\frac{100}{1}$

in the fœtus and young subject, but it is doubtful whether the formation of ova from cells of the germ-epithelium proceeds further in the adult.

Within the epithelium a firm layer of fibrous tissue encloses all the deeper parts. This has been compared to the dense fibrous covering of the testicle, and thence named *tunica albuginea ovarii*, but without sufficient reason, for it is not a distinct tunic, and is in fact no more than a condensed part of the ovarian stroma.

The *stroma* is chiefly composed of a fine connective tissue, in which the cells, many of which are spindle-shaped, are remarkably abundant and distinct. Besides the spindle-shaped cells, others are met with which closely resemble the interstitial

cells of the intertubular substance of the testis. Like these, they have a polyhedral or irregular shape and often a yellowish colour, and they are chiefly found accompanying the blood-vessels, although in older ovaries they may be very extensively diffused throughout the stroma. The stroma also contains elastic tissue, and is permeated by blood-vessels, which are large towards the hilum and in the centre of the ovary where the tissue is more fibrous, and become gradually smaller towards the surface. Along these blood-vessels in the deeper part of the ovary bands of muscular fibres run, having entered from the broad ligament ; but it is uncertain whether they extend into the more superficial parts of the ovarian stroma. According

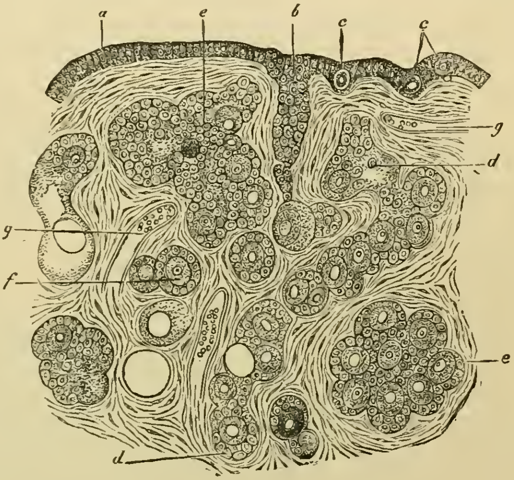


Fig. 285.—Section of the ovary of a newly-born child. Highly magnified. (Waldeyer.)

a, Ovarian or germinal epithelium ; *b*, formation of an ovarian tube ; *c*, *c*, primordial ova lying in the germ epithelium ; *d*, *d*, longer tube becoming constricted so as to form nests of cells ; *e*, *e*, larger nests ; *f*, distinctly formed follicle with ovum and epithelium ; *g*, *g*, blood-vessels.

to some authorities the spindle-shaped cells which characterize the ovarian stroma are also of a muscular nature. There is a general radial disposition of the bands of stroma from the hilum towards the surface.

Graafian follicles. — Immediately under the superficial covering of the ovary there is a layer of stroma somewhat different from the deeper parts, and which is so uniformly spread over the organ as to have received the name of cortical layer. This is particularly obvious in the ovaries of some animals (figs. 282, 283, 5) and of young children, in whom this layer is comparatively thick, and to the naked eye its appearance is granular from the accumulation in it of an immense number of closely set small vesicles, constituting the early condition of the ovarian or Graafian follicles with their contained ova. Embedded more deeply in the substance of the ovary are seen other larger and less numerous follicles of varying size, the largest being also the most deeply seated. The very largest, however, which are approaching maturity, eventually reach the surface again, owing to their being gradually more and more distended with fluid, and may there be seen projecting somewhat, in the form of clear vesicles, from one-twentieth to one-sixth of an inch in diameter. When these are punctured or ruptured a drop of clear fluid (*liquor folliculi*) escapes, carrying with it the minute ovum surrounded by an accumulation of the epithelium-cells of the follicle, known as the *discus proligerus*. Rupture of a Graafian vesicle, or it may be of more than one, occurs in healthy females at or before every successive menstrual period. After the discharge of its contents, the empty and collapsed Graafian follicle becomes filled with a peculiar reddish-yellow tissue and constitutes a body termed *corpus luteum*. Should pregnancy occur, this body undergoes a considerable development, which is maintained during the greater part of the time of utero-gestation. But in the unimpregnated female the corpus luteum begins to retrograde within ten or twelve days after its commencement, and soon shrinks and ultimately disappears. Other follicles, especially before and after the child-bearing period, may after advancing to a certain stage of development undergo a retrograde metamorphosis, their contents becoming broken up and

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liquefied and their walls collapsed and converted into a non-vascular homogeneous membrane. Follicles in this condition are not at all infrequent in the deeper parts of the ovary (fig. 286, *k*).

In addition to Graafian follicles in various stages of development and retrogression, there may also occasionally be seen in sections of the adult ovary and constantly in that of the young subject, cords or tubes composed of rounded or polyhedral cells, sometimes with developing ova imbedded amongst the other cells (fig. 286, *b*). These cords may be in con-

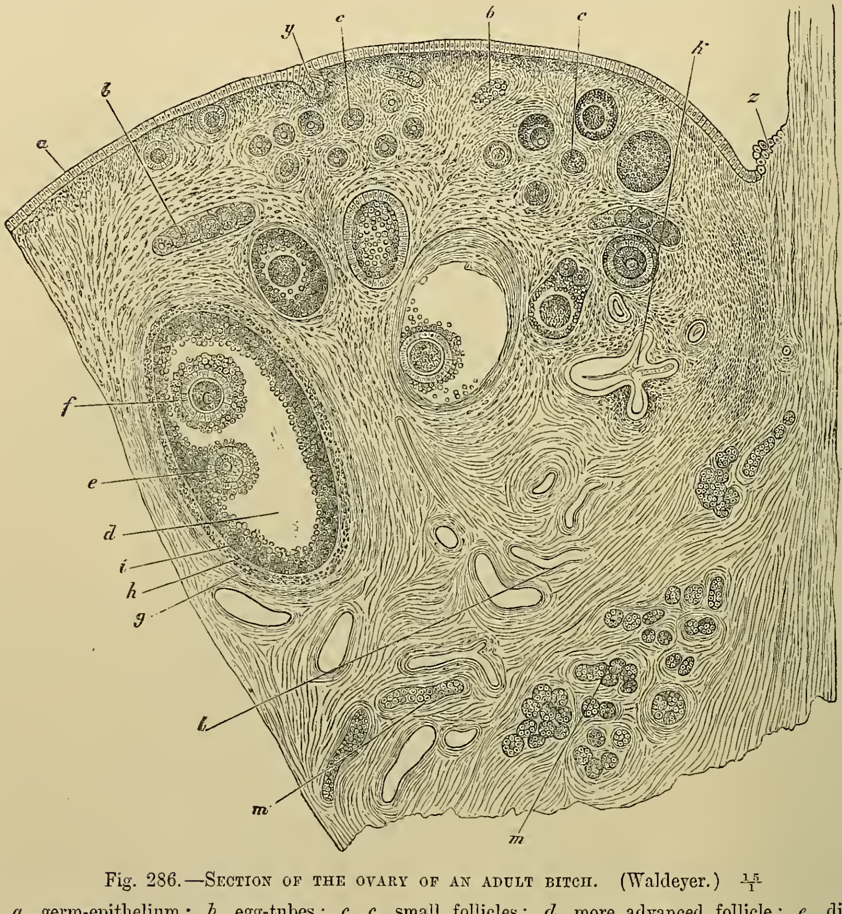


Fig. 286.—Section of the ovary of an adult bitch. (Waldeyer.) $\frac{15}{1}$

a, germ-epithelium ; *b*, egg-tubes ; *c*, *c*, small follicles ; *d*, more advanced follicle ; *e*, discus proligerus and ovum ; *f*, second ovum in the same follicle (this occurs but rarely) ; *g*, outer tunic of the follicle ; *h*, inner tunic ; *i*, membrana granulosa ; *k*, collapsed retrograded follicle ; *l*, blood-vessels ; *m*, *m*, longitudinal and transverse sections of tubes of the parovarium ; *y*, involuted portion of the germ-epithelium of the surface ; *z*, place of the transition from peritoneal to germinal or ovarian epithelium.

tinuity with the germinal epithelium or they may be altogether cut off from it. Others occur which are partially constricted into rounded nests of cells by growth of the stroma across the cords, and similar nests or groups are found entirely separated, and with or without a developing ovum in the centre. It is from such nests of cells that the Graafian follicles have become developed.

Structure of the Graafian follicles.—The smallest Graafian follicles have no proper wall. They consist merely of a single layer of cells, immediately investing the contained ovum (fig. 284). In section, the cells are flattened and look spindle-shaped in the human subject, and not very unlike the cells of the ovarian stroma, so

that they have been thought to be derived from those cells; but the observations of Balfour and others upon the lower animals tend to confirm the view which was first taken by Waldeyer that, like the ova themselves, the epithelium-cells of the follicles are originally derived from the germinal epithelium. These smallest

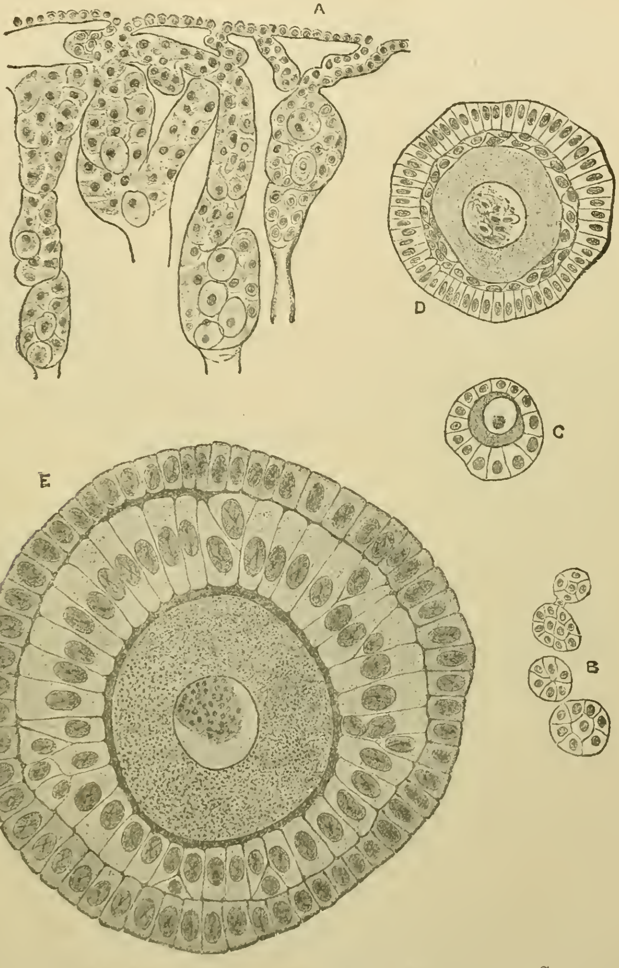


Fig. 287.—Figures showing various stages in the development of the Graafian follicles in the rabbit. Highly magnified. (E. A. S.)

A, From a section of the ovary of a young rabbit, showing the "egg-tubes" of Pflüger continuous with the germinal epithelium of the surface, from which they are developed somewhat after the manner of tubular glands. Some of the egg-tubes contain primitive ova. B, primitive Graafian follicles derived from the breaking up of an egg-tube. C, a Graafian follicle within which the permanent ovum has now become distinct. The follicle has only a single layer of epithelium. D, a larger follicle in which there are two distinct layers of epithelium, but the inner layer is formed of flattened cells. E, a larger but still quite young follicle in which the inner layer of cells as well as the outer is composed of columnar epithelium. Figs. B, C, D, and E are taken from sections of ovaries more advanced in development than A.

follicles are very numerous, especially in the young subject; indeed, it has been computed that in the ovaries of a female child at birth there cannot be fewer than 70,000 of them. If this is the case, a large proportion must degenerate and disappear without coming to maturity. Their size is about $\frac{1}{100}$th of an inch (·25 mm.).

In follicles which are a little larger, and situated somewhat more deeply in the stroma, the epithelium-cells, although still in a single layer, are no longer flattened but cubical (fig. 287, C) ; a *membrana propria* or basement membrane can be detected, and the layer of stroma next to the follicle is beginning to be somewhat differentiated from the rest so as to form a special fibrous wall to the follicle. In others again a second layer of cells is beginning to be formed or may be found entirely formed within the first, and of the two layers thus produced, one immediately invests the ovum, and the other lines the wall of the follicle (fig. 287, D). The former is the beginning of the *discus proligerus,* and the latter of the *membrana granulosa.* The cells of both layers soon become columnar (fig. 287, E).

In follicles which are still larger, fluid is seen to be accumulated between the two layers of cells, and thus to distend the follicle. This collection of fluid is absent at one part, generally that which is directed away from the surface of the ovary, so that here the cells which surround the ovum are in continuity with those which line the follicle, and the ovum is thus in a manner attached at this place to the wall of the follicle (see fig. 283). In the largest follicles the chief difference in the contents of the follicle consists in the far greater accumulation of the liquor folliculi, and in the multiplication of the epithelium-cells—both those which line the follicle (membrana granulosa) and those which invest the ovum (discus proligerus)—so that each of these parts consists, in large follicles, of several layers of cells, mostly rounded or irregular, but columnar next to the wall of the follicle and the exterior of the ovum respectively.

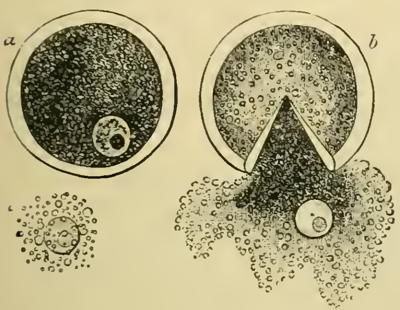
The larger follicles have a very distinct wall, which is continuous with and derived from the stroma of the ovary, and is separable into two parts, an inner containing the ramifications of the capillary blood-vessels, which are abundantly distributed to the larger follicles, but nowhere penetrate amongst the epithelium cells ; and an outer part more fibrous, in which the larger branches of the blood-vessels of the follicle run. In both layers of the follicular wall, the cells are similar to those of the general stroma, interstitial cells occurring abundantly ; but it is uncertain whether there are any cells present of the nature of muscular fibres. The smaller blood-vessels running round the follicle from its deepest part, and minutely sub-divided on its inner surface, converge towards a point near the middle of the most projecting part, called the *stigma.* This marks the spot where the rupture of the vesicle ultimately occurs, when fully matured.

Each Graafian follicle usually contains only a single ovum ; but occasionally, though seldom, two ova, and very rarely three, are observed in the same follicle. The structure of the ovum has already been described in Vol. I., pt. 1 ; but for the sake of completeness the description of the human ovum may be here repeated.

Structure of the ovarian ovum.—The human ovum resembles that of all other mammals (with the exception of monotremes) in its minute size. Immediately before the time of its discharge from the Graafian follicle of the ovary in which it has been formed, it is a small spherical vesicle measuring about $\frac{1}{125}$th inch (·2 mm.) in diameter, and is just visible as a clear speck to the naked eye. When examined with the microscope, it is found to be invested by a comparatively thick, clear covering. This, when the centre of the ovum is exactly focussed, has the appearance in optical section of a clear girdle or zone encircling the ovum (fig. 288), and was hence named *zona pellucida* by von Baer (1827). But on more careful examination with higher magnifying powers, and especially by the examination of sections, there is not much difficulty in making out the existence of striæ passing radially through the membrane (fig. 289, *zp*). On this account, and especially since a similar radially striated membrane forms a characteristic part of the investment of the ovum in many animals belonging to widely different classes, it is more convenient, in place of the name zona pellucida, which has been exclusively used to designate

this investment in mammals, to employ the more general term *zona radiata*, or to speak of it simply as the *striated membrane* of the ovum.

The zona radiata of the mammalian ovum is sufficiently tough to prevent the escape of the contents of the ovum, even when subjected to a considerable amount of pressure. If, however, the pressure be excessive, the tunic splits, and the soft contents are extruded (fig. 288, *b*). The striæ in the membrane are believed to be minute pores, and are supposed, while the ovum is yet within the Graafian follicle, to permit the passage of granules of nutrient material into the interior of the ovum. After the ovum is discharged from the follicle, the spermatozoa may perhaps find their way into the ovum through these pores. According to Retzius



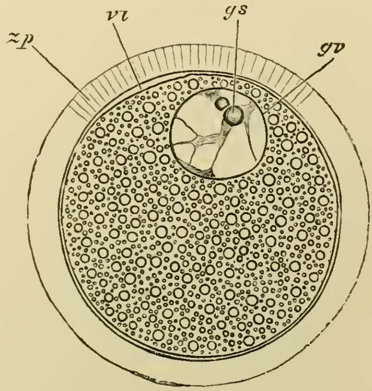


Fig. 288.—Ovarian ovum of a mammal. (Allen Thomson.)

a, an entire ovum, viewed under pressure ; the granular cells have been removed from the outer surface, the germinal vesicle is seen in the yolk substance within ; *b*, the external coat or zona burst by increased pressure, the yolk protoplasm and the germinal vesicle having escaped from within ; *c*, germinal vesicle more freed from the yolk substance. In all of them the macula is seen.

Fig. 289.—Ovum of a mammal ; highly magnified. semi-diagrammatic. (E. A. S.)

zp, zona pellucida, showing radiated structure ; *vi*, vitellus, round which a delicate membrane is seen ; *gv*, germinal vesicle ; *gs*, germinal spot.

the protoplasm of the ovum is united with the follicle-cells by fibres which pass through the pores of the zona.

Immediately surrounding the zona radiata, as the ovum lies within the mature Graafian follicle, is a thin stratum of granular substance, probably deposited upon the exterior of the ovum by the innermost cells of the discus proligerus, which immediately encircle the ovum within the follicle. When the Graafian follicle bursts and the ovum is set free, this granular material appears to imbibe water, and, as is specially noticeable in the ovum of the rabbit, swells up into a clear gelatinous envelope, which has been termed, from a possible homology with the white of the bird's egg, the *albumen*. But in the mammal this structure has not the nutritive importance to the embryo which is possessed by the corresponding formation in the bird, and it disappears during the passage of the ovum down the Fallopian tube.

The substance of the ovum within the tunica radiata is known as the *vitellus* or *yolk* (fig. 289, *vi*). It is a soft semi-fluid substance, composed mainly of protoplasm, which is filled with globules and granules (yolk-granules) of different sizes, but all small, and possessing a high index of refraction. Examined in the fresh condition, the protoplasm between the granules looks perfectly clear and structureless, but after treatment with suitable reagents, it may be seen to consist of a fine reticulum, which is especially fine and close near the periphery of the ovum, and also around the germinal vesicle, at which places the yolk-granules are in less amount than elsewhere. The substances which occur within an ovum other than

the nucleus and protoplasm, may, as in cells generally, be collectively designated "deutoplasm"; they are regarded as furnishing a supply of nutrient matter to the protoplasm during the earlier stages of development.

Embedded in the protoplasmic vitellus, usually eccentrically, is a large spherical nucleus, which was termed by its discoverer, Purkinje, the *germinal vesicle*.[1] This, which is about $\frac{1}{500}$th inch (·05 mm.) in diameter, has all the characters of a nucleus of a cell. It consists of a nuclear membrane (fig. 289, *gv*) enclosing a clear material or matrix, embedded within which may be seen strands of karyoplasm, enclosing one or more well-marked nucleoli. Frequently there is but one nucleolus, which is then large and prominent, and has received the name of *germinal spot* (*macula germinativa*, Wagner, 1835).

There is some doubt whether, before fertilization, there is another membrane (vitelline membrane) enclosing the vitellus within the zona radiata. The evidence of the presence of such a membrane is by no means clear, although its existence has been maintained by very competent observers (v. Beneden, Balfour).

Structure of the corpora lutea.—The corpora lutea are produced after the rupture of the Graafian follicles and the escape of their contents by what may

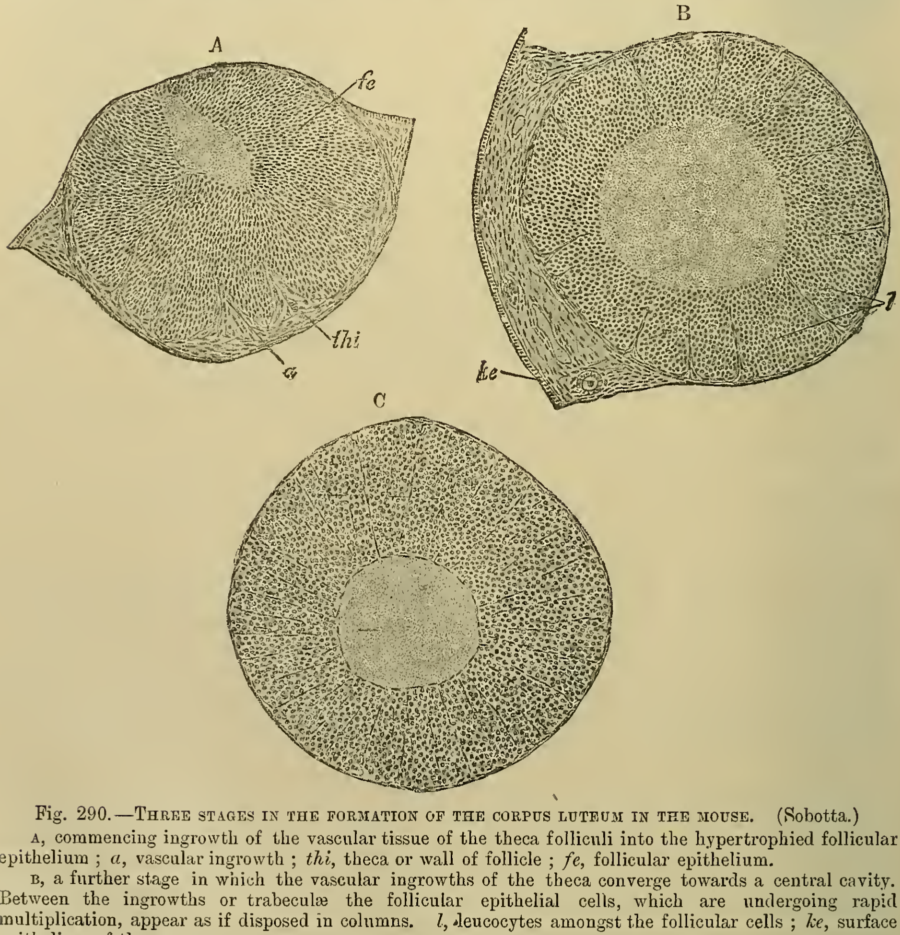


Fig. 290.—Three stages in the formation of the corpus luteum in the mouse. (Sobotta.)

A, commencing ingrowth of the vascular tissue of the theca folliculi into the hypertrophied follicular epithelium; *a*, vascular ingrowth; *thi*, theca or wall of follicle; *fe*, follicular epithelium.

B, a further stage in which the vascular ingrowths of the theca converge towards a central cavity. Between the ingrowths or trabeculæ the follicular epithelial cells, which are undergoing rapid multiplication, appear as if disposed in columns. *l*, leucocytes amongst the follicular cells; *ke*, surface epithelium of the ovary.

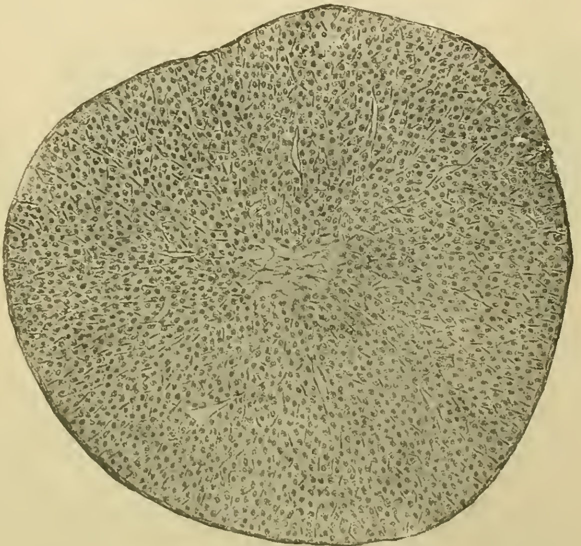
C, a further stage, the columns being now narrower and the trabeculæ more numerous.

[1] Purkinje discovered the germinal vesicle in the bird's ovum in 1825; that of mammals was first noticed by Coste in 1833.

perhaps be most correctly described as a process of hypertrophy, *i.e.*, growth of the walls of the empty follicles. The hypertrophied follicular wall becomes thrown into plaits or folds which as they increase in extent occupy more and more of the cavity of the empty follicle, until this has become entirely filled. The hypertrophy is usually described as the result of the proliferation of the polyhedral interstitial stroma-cells, which as already stated occur in the wall of the follicle in abundance, and there is in addition a considerable development of blood-vessels, which run, accompanied by fibrous tissue, into the folds into which the wall of the follicle is

Fig. 291.—More advanced corpus luteum of the mouse, showing its formation completed. (Sobotta.)

The central cavity is now occupied by jelly-like connective tissue and the converging trabeculæ anastomose with one another so as somewhat to break up the columnar arrangement of the luteal cells.

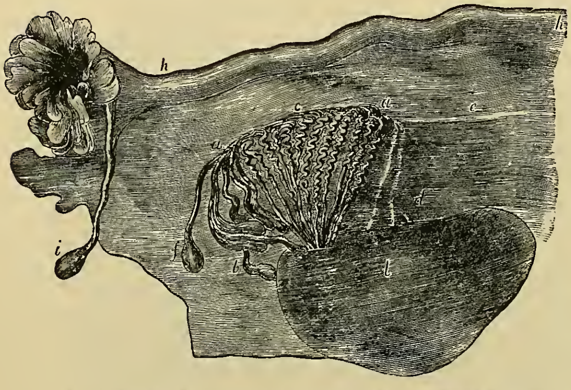


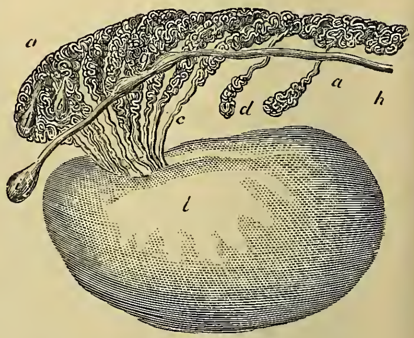
thrown, giving off capillaries which ramify abundantly in the folded wall. But according to the observations of J. Sobotta upon the mouse, the main part of the thickening is due to a simple hypertrophy of the epithelium-cells of the membrana granulosa, into which vascular processes of the wall of the follicle grow and amongst which a certain number of leucocytes penetrate (fig. 290). Meanwhile the irregular cleft-like space which now alone represents the cavity of the follicle, as well as the opening resulting from the rupture of the follicle and by which its cavity communicated with the surface, become occupied by a sort of jelly-like connective tissue, which constitutes a kind of hilum for the follicle. To this central fibrous band the strands of fibrous tissue which accompany the blood-vessels in the folds of the hypertrophied wall of the corpus luteum converge. At the same time the plaited disposition of the wall becomes in great measure obscured, so that a section of a corpus luteum, when advanced in development (fig. 291), exhibits a fibrous framework having a radial disposition, with the intervals between the radiating trabeculæ occupied by a tissue which is almost wholly composed of large yellowish cells. Amongst these cells are numerous cleft-like spaces (lymphatic), and except for the fact that the columnar disposition is less distinct and that the capillary blood-vessels come more closely into relationship with the cells of the tissue, the structural appearances are not unlike those which are met with in the cortical part of the suprarenal capsule.

The corpus luteum is at first sharply marked off by the theca folliculi from the surrounding ovarian stroma, but after a time its limits are less well defined from the neighbouring parts of the stroma, into which it may be said gradually to merge and in this way to disappear. The result is that, as age advances, the stroma of the ovaries, at least in some animals, becomes gradually pervaded with cells like those of the corpora lutea.

Vessels and nerves of the ovaries.—Arteries.—The ovaries are most directly

supplied by the *ovarian arteries*, analogous to the spermatic in the male, which anastomose freely by an internal branch with the termination of the uterine arteries. Sometimes this anastomotic branch is so large that the ovary seems to be supplied almost entirely by the uterine artery. The ovarian artery always sends numerous branches to the Fallopian tube. The smaller arteries penetrate the ovary along its attached border, pierce the proper coat, and run in flexuous parallel lines through its substance. The **veins** correspond, forming a plexus near the ovary named the *pampiniform plexus.* The **nerves** are derived from the *ovarian plexus;* and also from the uterine nerves, which invariably send offsets to the Fallopian tubes. The nerves are





TWO FIGURES EXHIBITING A COMPARISON BETWEEN PARTS OF THE GENERATIVE ORGANS IN THE TWO SEXES (from Farre, after Kobelt).

Fig. 292.—ADULT OVARY, PAROVARIUM AND FALLOPIAN TUBE.

a, a, Epoophoron (parovarium) formed from the upper part of the Wolffian body; *b,* remains of the uppermost tubes, sometimes forming hydatids; *c,* middle set of tubes; *d,* some lower atrophied tubes; *e,* atrophied remains of the Wolffian duct; *f,* the terminal bulb or hydatid; *h,* the Fallopian tube, originally the duct of Müller; *i,* hydatid attached to the extremity; *l,* the ovary.

Fig. 293.—THE ADULT TESTIS AND EPIDIDYMIS.

a, a, convoluted tubes in the head of the epididymis developed from the upper part of the Wolffian body; *b* and *f,* hydatids in the head of the epididymis; *c,* coni vasculosi; *d,* vasa aberrantia; *h,* remains of the duct of Müller with *i,* the hydatid of Morgagni, at its upper end; *l,* body of the testis.

said by Gawronsky to penetrate even amongst the epithelium cells of the membrana granulosa of the Graafian follicles.

Parovarium.—The organ so named by Kobelt, or the *organ of Rosenmüller,* who first described it, is a structure which can usually be brought plainly into view by holding against the light the fold of peritoneum between the ovary and Fallopian tube (see fig. 292, *a, b, c, d*). It consists of a group of scattered tubules lying transversely between the Fallopian tube and ovary, lined with epithelium, but having no external openings. The tubules converge towards their ovarian end, but remain separate there, while at the other they are more or less distinctly united by a longitudinal tube which is sometimes of considerable size, and prolonged for some distance downwards in the broad ligament. Its more developed form in some animals, as the cow and pig, constitutes the *duct of Gartner.* The origin of this vestige of a fœtal structure is referred to under Development (Vol. I. part 1, p. 120). Here it is sufficient to state that it corresponds essentially to the epididymis of the male. Vestiges corresponding to the organ of Giraldès of the male are also sometimes to be detected in the adult female, in the shape of tubular remnants, situated in the broad ligament nearer to the uterus than the parovarium. These constitute the *paroophoron* of Waldeyer; the organ of Rosenmüller constituting the *epoophoron.*

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MAMMARY GLANDS.

The mammary glands (*mammæ*), which yield the milk in the female, are accessory parts to the reproductive system. They give a name to a large class of animals (Mammalia) which are distinguished by the possession of these organs. When fully developed in the human female, they form, together with the integuments and a considerable quantity of fat, two hemispherical or conical eminences (the breasts) placed one at each side on the front of the thorax. A little below the centre of each breast, on a level with the fourth rib, or slightly lower, projects a small cylindrical or conical body named the nipple (*mamilla*), which points somewhat upwards and outwards. Each gland is situated in the superficial fascia, and extends, in a vertical line passing through its nipple, from the second to the sixth or seventh rib, and in a horizontal line, through the same structure, from a little internal to

Fig. 294.—Dissection of the lower half of the female mamma during the period of lactation (from Luschka). $\frac{2}{3}$

a, *a*, *a*, undissected part of the mamma; 1, the mamilla; 2, areola; 3, subcutaneous masses of fat; 4, loculi in the connective tissue which supports the glandular substance; 5, three lactiferous ducts passing towards the mamilla where they open; 6, one of the sinuses or ampullæ; 7, some of the glandular lobules which have been unravelled; 7′, others massed together.

the lateral border of the sternum opposite the fourth costal cartilage to the fifth intercostal space opposite the mid-axillary line,[1] and measures some $4\frac{1}{2}$ inches (112 mm.) from above down; about 5 inches (128 mm.) across; and about 2 inches (54 mm.) thick. The average weight of each gland in the virgin is from 150 to 200 grammes; in the nursing woman from 400 to 500 grammes (Testut).

Structure of the nipple.—The surface of the nipple is dark, and around it there is a coloured circle or *areola*, within which the skin is also of a darker tinge than elsewhere. In the virgin, these parts are of a rosy pink colour, differing somewhat according to the complexion of the individual, but they are always darker in women who have borne children. Even in the second month of the first pregnancy, the areola begins to enlarge and acquire a darker tinge; these changes go on

[1] The lateral extension of the mammary gland given above is based upon the observations of Stiles, Edin. Med. Journal, 1892.

increasing as gestation advances, and are regarded as signs to be relied on in judging of suspected pregnancy. After lactation is over, the dark colour subsides, but never entirely disappears. The skin of the nipple is marked with many wrinkles, and is covered with papillæ; besides this, it is perforated at the tip by

Fig. 295.—Transverse section of the nipple. (Testut, after de Sinéty.)

a, sections of galactophorous ducts, with, *e*, columnar epithelium; *b*, connective tissue; *m*, *m'*, plain muscular fibres cut longitudually and transversely respectively; *v*, bloodvessels.

numerous foramina, which are the openings of the lactiferous ducts; and near its base, as well as upon the surface of the areola, there are scattered rounded elevations, which are caused by the presence of well-marked sebaceous glands with branched ducts four or five of which open on each elevation. The sudoriparous glands of the areola are also large and much convoluted, but there are no sudoriparous glands in the nipple proper nor are there any hair follicles here. The tissue of the nipple contains a large number of vessels together with much plain muscular tissue, and its papillæ are highly sensitive; it becomes firmer and more projecting from mechanical excitement, a change caused by contraction of the muscular fibres, which form concentric circles round the base of the nipple and radiating bands running from base to apex.

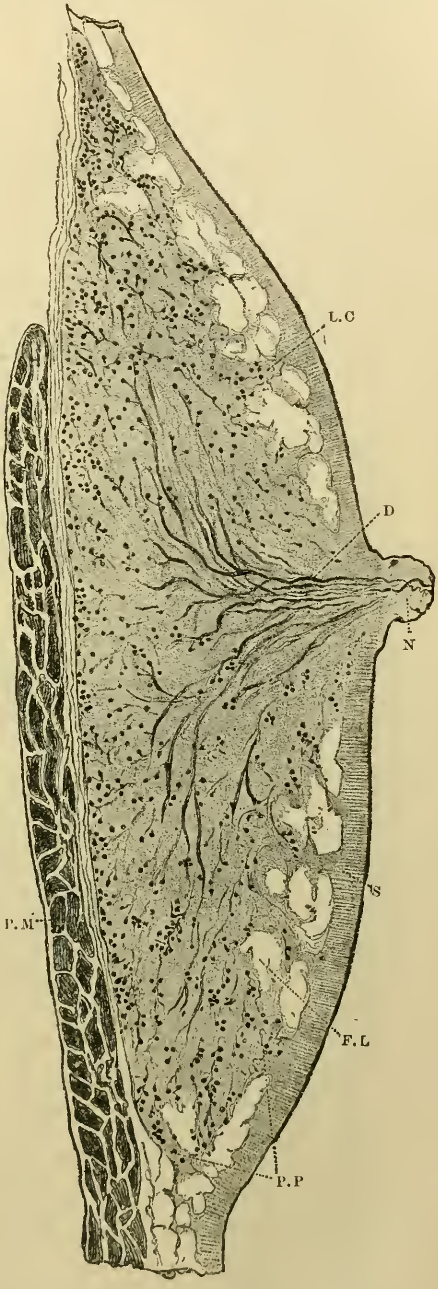
Structure of the mamma.—The mamma is composed of glandular tissue, supported by a connective tissue stroma in which the blood-vessels, lymphatics and nerves ramify. It also comprises a greater or less amount of adipose tissue. The relative amount and distribution of these constituents varies considerably according to the age of the individual, and whether the gland is, has been, or has not been, functionally active. In the adult nullipara the gland is usually a firm conical mass with its apex at the nipple. This part is called the *corpus mammæ*; from it peripheral processes extend in various directions. Under the nipple and areola the stroma is entirely devoid of fat, but towards the circumference a few fat lobules may be embedded in it. The anterior surface of the gland is convex, but uneven, owing to the presence of numerous irregular processes passing towards the skin, with which

some of them are united by bands of connective tissue, the so-called *ligaments of Cooper*. Lobules of fat occupy the intervals between these processes. The posterior

Fig. 296.—Horizontal section of the mammary gland at the level of the nipple in a nulliparous female aged 27 years. (Stiles.) $\frac{1}{1}$

The specimen was kept for 2 days in a 5 p. c. solution of nitric acid, then washed in water and preserved in methylated spirit.

N, nipple; S, skin; L.C, ligament of Cooper connecting a process of the gland with the skin; P.P, peripheral processes; F.L., fat lobules; P.M, pectoralis major muscle.



surface of the gland is flat or slightly concave, and much more even than the anterior, as the corpus mammæ is bounded here by a smooth compact layer of gland tissue. Delicate glandular processes do, however, extend from this aspect into the retromammary tissue, reaching close to the subjacent muscles and even, according to Heidenhain, passing into the pectoralis major. The upper and inner portion of this surface, comprising about two-thirds of its whole extent, lies upon the pectoralis major; external to this muscle the posterior surface rests on the axillary fascia which separates it from the serratus magnus, and lower down it is in relation with the digitations of the serratus magnus and external oblique which arise from the fifth and sixth ribs (Stiles). The edges of the mamma are not sharply defined as, at its periphery, the corpus mammæ breaks up into numerous irregular processes which branch and unite to form a reticular formation enclosing lobules of fat. The stroma of the peripheral processes, where the gland tissue ceases, becomes directly continuous with the connective tissue framework of the adjacent fat lobules. At puberty the gland appears on external examination to be well developed, but it really consists mainly of stroma and excretory ducts, the true secreting acini being few in number. During lactation the gland tissue proper undergoes a marked development, and the stroma is relatively reduced in amount, so that on section the gland presents to the naked eye a close resemblance to a salivary gland. After the period of functional activity is ended the gland returns by a process of involution to its resting stage, but it does not regain the appearances it exhibited before pregnancy. Thus the corpus mammæ is less distinct, and its stroma is looser and contains numerous fat lobules, while

the peripheral processes are larger and have a more extensive distribution. A layer of fat of greater or less thickness is now found between the gland and the deep fascia.

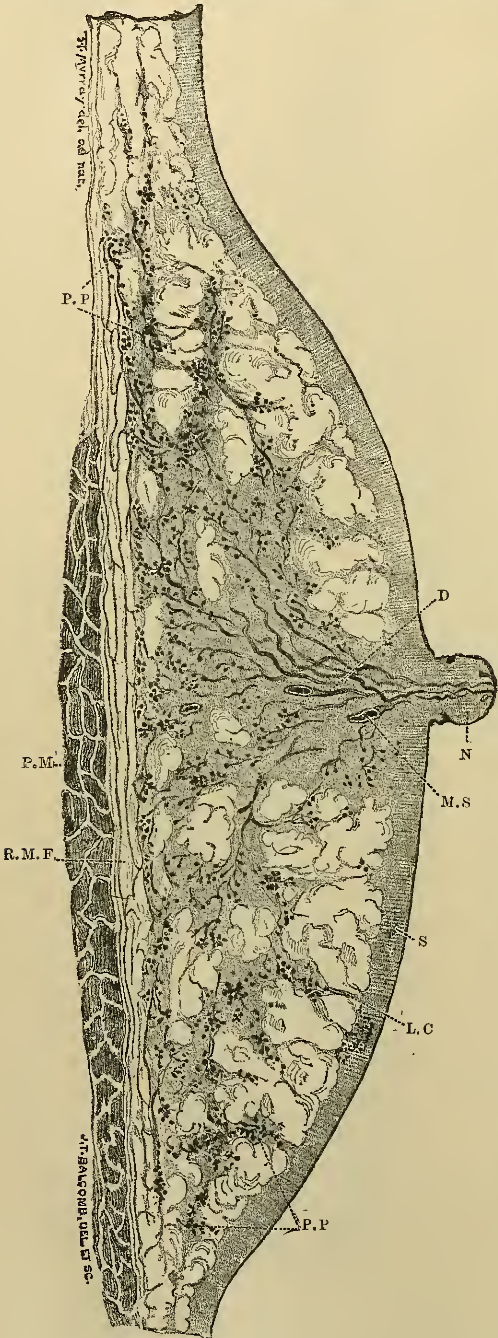


Fig. 297.—Horizontal section of the mammary gland at the level of the nipple in a multipara, aged 40. The specimen was treated in the same way as that shown in fig. 296. (Stiles.) $\frac{1}{1}$

M.S, sinus or ampulla of milk duct; R.M.F, retromammary fat; other letters as in fig. 296.

After the menopause the appearance of the gland varies according to the general condition of the subject. Thus in thin women it forms a somewhat flattened disc which comes into close relation both with the skin and the subjacent muscles, while in obese women the mamma is composed mainly of fat, the stroma investing the parenchyma forming a wide open meshwork, except in the immediate vicinity of the nipple.

The glandular substance of the mamma consists of numerous distinct lobes, twelve to twenty in number, held together by firm intervening fibrous or areolar tissue, and having adipose tissue penetrating between them. Each of these lobes is provided with an excretory duct, and is subdivided into smaller lobes, and these again into the lobules which are beset with the alveoli. Each lobe is practically a distinct gland, although the lobes come into close contact with one another. Sometimes, besides the principal lobes, small accessory lobes or glands are met with near the base of the nipple. The lobules are separated from one another in the human subject by a large quantity of areolar tissue (fig. 298). The interlobular tissue contains numerous plasma-cells. The substance of the lobules is of a pale reddish cream-colour, contrasting with the adjacent fat, and is rather firm. The excretory ducts, named the *galactophorous ducts*, are, like the lobes, about twenty in number; they converge towards the areola, beneath which they become considerably dilated, especially during lactation, so as to form *ampullæ* or *sinuses* about 12 mm. long and 6 mm. wide (fig. 294, 6), which serve as small temporary reservoirs for the milk. At the base of the nipple all these ducts, again reduced in size, are assembled together, those in the centre being the largest, and

then proceed, side by side, surrounded by areolar tissue and vessels, and without communicating with each other, to the summit of the mamilla, where they open by separate orifices; these orifices are seated in little depressions, and are smaller than the ducts. The walls of the ducts are composed of areolar tissue, with longi-

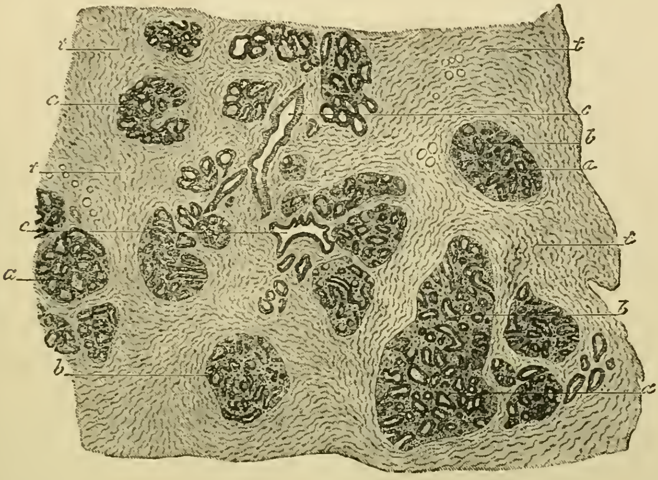


Fig. 298.—Section of mammary gland of woman during lactation. (Testut, after de Sinéty.)
a, lobule of gland; *b*, acini lined by cubical epithelium; *c*, duct; *t*, connective tissue stroma.

tudinal and circular elastic fibres but without muscular tissue. The membrana propria of the alveoli is described as consisting of a homogeneous membrane having stellate and anastomosing cells upon its inner surface next to the epithelium.

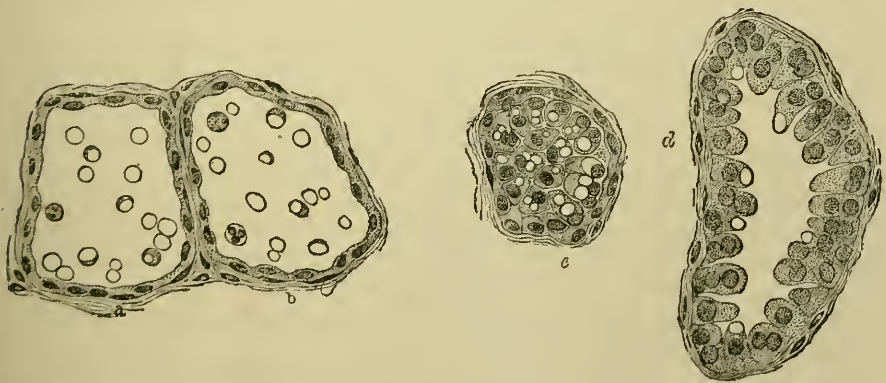


Fig. 299.—Alveoli of the mammary gland of the bitch under different conditions of activity. (Heidenhain.)
a, *b*, section through the middle of two alveoli at the commencement of lactation, the epithelium cells being seen in profile; *c*, part of the wall of an alveolus in a similar condition with the epithelium cells seen flat; *d*, an alveolus in full secretory activity.

Both the alveoli and the ducts are lined with a simple layer of epithelium, which is flattened in the alveoli and in the lobular ducts; cubical in the larger ducts and columnar in the excretory ducts and ampullæ. Near the external openings on the nipple it becomes scaly stratified.

The epithelium differs in its appearance according to the state of activity of the gland. When entirely inactive the alveoli are very small, and the epithelium cells

small and granular. At the commencement of lactation the alveoli enlarge and become distended with clear secretion (fig. 299, *a*, *b*); the cells are flattened out against the membrana propria and contain fat globules of varying size and in the fluid contents of the alveoli besides similar fat globules, some of which have a partial surrounding of protoplasm, a few uni- or multi-nucleated granular cells are seen. During full activity the cells become cubical or even columnar, but are irregular in size and exhibit indications of division and of budding off into the interior of the alveoli (fig. 299, *d*). By the breaking down of parts of the cells which have thus become free in the alveoli the constituents of the milk appear to be formed, the fat globules which were present within the cells becoming suspended in the fluid of the alveoli as milk globules, and the albuminous constituents of the cells becoming dissolved and forming the casein and other proteid substances of the milk.[1]

There is a rich network of blood-capillaries investing the alveoli, and the alveoli are surrounded by sinus-like lymphatics, as in other racemose glands.

In the adult male the mammary gland and all its parts exist, but quite in a rudimentary state, the gland itself measuring only from half to three-quarters of an inch across, and one-sixth of an inch thick. Occasionally the male mamma, especially in young subjects, enlarges and gives out a thin watery fluid; and, in rare cases, it has secreted milk.

Blood-vessels, Lymphatics, and Nerves.—The **arteries** which supply the mammary glands are the *long thoracic* and some other branches of the axillary artery, the *internal mammary*, and the subjacent *intercostals*. The **veins** have the same denomination. Haller described a sort of anastomotic venous circle surrounding the base of the nipple as the *circulus venosus*. The **lymphatics** within the mammary gland form plexuses in the connective tissue around the alveoli and ducts. There are also lymphatics which accompany the blood-vessels in the gland, and, as elsewhere, the smaller blood-vessels have usually a single accompanying lymphatic vessel of much larger calibre than the artery itself, while the sheaths of the larger vessels contain two or three lymphatics (Stiles). These perivascular lymphatics communicate freely with those around the lobules and ducts of the gland. In addition to the intramammary lymphatics there are four other sets of vessels connected with the mammary lymphatic system, viz., *cutaneous*, *subareolar* of Sappey, *circummammary*, and *retromammary*. The lymphatics from the inner part of the gland pass with the perforating branches of the internal mammary artery to join the small sternal glands situated along the course of this vessel. On the outer side of the gland the vessels are much larger and unite to form two or three principal trunks which pass to lymphatic glands in the axilla. The **nerves** proceed from the anterior and lateral *intercostal* cutaneous branches. They pass partly to the glandular substance and blood-vessels, partly to the skin. In the nipple many of them end in tactile corpuscles within the papillæ, and some of those in or near the areola enter Pacinian corpuscles.

Varieties.—Entire absence of both glands and nipples is very rare; a few such instances, however, are recorded in otherwise normally developed individuals. Thus Wylie met with a case in a woman, aged twenty-one years. A small mole existed where the right nipple is normally situated. Batchelor describes a similar condition in an adult female, but in this instance the usual position of each nipple was occupied by a small area of pigmented skin. In a boy three-and-a-half years old J. Hutchinson found complete absence of both mammary glands, associated with absence of hair and an atrophic condition of the other integumentary appendages. Absence of one mammary gland is almost as uncommon as that of both, and is usually associated with an imperfect development of the thoracic wall on the same side. The glands themselves may be well formed, but the nipples absent. Such cases are of interest in connection with the fact that in the ornithorhynchus there are no nipples, the mammary secretion being discharged on to a plane surface; further in the development of the

[1] This is the view which was taken by R. Heidenhain (Hermann's Handbuch der Physiologie, Bd. v.,) but it is doubtful if it is really correct. For a critical account of this and other views which have been taken as to the changes in the cells which accompany secretion, see article, "Secretion of Milk," Text-book of Physiology, edited by E. A. Schäfer, vol. i., 1898. [Note added August, 1898].

mammary gland the papillary elevation of the skin giving rise to the nipple is secondary to the epithelial downgrowth from which the gland itself is formed.

In the majority of mammals more than two glands are normally present, indeed in some of the Insectivora there are as many as eleven pairs. It has been shown by O. Schultze that in the embryo of various mammals, such as the cat, rabbit, and mole, a line of thickened epithelium is formed on each side of the trunk extending from the axilla downwards and inwards to the groin. It is in this situation that the mammary glands are usually developed in polymastic mammals, and in the great majority of cases of additional glands in the human subject they are found in a corresponding position and may be designated axillary, pectoral, abdominal, inguinal or vulval mammæ. The supernumerary mammary structures are usually represented by the nipple only, but in some cases the glandular tissue is well developed and may be functionally active. Most of the cases of additional mammæ appear, on one or both sides, just below and internal to the normal pair. The largest number of additional glands that has hitherto been recorded is eight. In this instance, which was described by Neugebauer in a woman aged twenty-three, there were three pairs of nipples above the normal ones, and one pair below. It is probable that in this case, as Roger Williams suggests, the two nipples below the normal pair did not represent a pair of glands, but single examples of two pairs, as the right one was some inches higher up than the left. If such be the case there were representatives of six pairs of glands in this woman. Ammon has described a case of three additional pairs of nipples in a man aged twenty-two years. One pair was placed above the normal nipples on the anterior folds of the axillæ, another near the lower margin of the chest wall, and the lowest on the anterior wall of the abdomen above the level of the umbilicus. Bardeleben concludes from his most recent investigations that the normal pair of glands represents a persistence of the sixth pair counting from above downwards. Various cases of mammary glands appearing in the axilla during pregnancy have been regarded as examples of excessive development of the cutaneous glands of that region, or of a more or less complete separation of that process of the normal gland which extends into the axilla. A few cases have been recorded of mammary glands (*mammæ erraticæ*) being found over the acromion process, on the upper part of the thigh, or even on the back. Sometimes two or more nipples occur on one gland.

Milk.—The milk is characterized by containing an immense number of fat-globules of varying size but averaging from $\frac{1}{12000}$th to $\frac{1}{5000}$th of an inch in diameter. They appear to be coated with an exceedingly thin investment of albuminous substance, probably casein, which prevents them from running together into larger drops, but when this is dissolved by the addition of an acid, they readily blend with one another. Rarely there is a more distinct

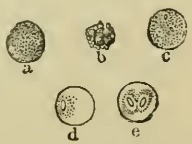


Fig. 300.—Constituents of the colostrum. (Heidenhain.)
a, b, colostrum-corpuscles with fine and coarse fat globules respectively; *c, d, e,* pale cells devoid of fat globules.

envelope of granular substance, occasionally containing a nucleus, and free nuclei have also been described as existing to a small extent in the milk.

The mammary gland before and during the first two or three days after parturition yields a small amount of a turbid fluid termed the *colostrum*. This contains besides milk-globules single and in groups, amœboid cells, containing small or large fat-globules, either closely packed within the cell, or but few in number, and sometimes absent altogether: in the latter case permitting the nucleus to be visible (fig. 300). These amœboid cells are known as the "colostrum-corpuscles" ("granular corpuscles" of Donné): they occur either not at all or but very rarely, when the gland is in full activity. It is uncertain whether they originate as separated epithelium cells of the alveoli, or whether they are emigrated white corpuscles.

Development of the Mammary Gland.—The first sign of the gland shows itself at the end of the second month in the human embryo in the shape of a thickening and downgrowth of the rete mucosum of the epidermis at the site of the future nipple. The thickening spreads laterally so as to correspond with a small area (mammary area) which soon becomes sunk below the general surface. From the thickened rete mucosum of this area special outgrowths of the epithelium into the cutis vera occur, one for each of the lobes of the future gland. These outgrowths, as with other racemose glands, become branched, and their branches end in enlargements. The formation of these sprouts goes on until birth, but the development of glandular alveoli from them does not occur until the approach of puberty in the female, and in the male not at all. The projection of the nipple from the rest of the mammary area does not begin until about the first year after birth; within it a large amount of plain muscular tissue becomes formed. The remainder of the mammary area becomes the areola.

The subsequent growth of the gland is comparatively tardy. At the third or fourth year of infancy, there is little or no difference in male and female children. The fuller develop-

ment of the gland in the female occurs only towards puberty. It is probable that during the later period of pregnancy, not only do the alveoli increase in size, but new alveoli may bud laterally from the pre-existing ones, and that after lactation some of the alveoli may become atrophied and disappear.

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THE DUCTLESS GLANDS.

By E. A. SCHĀFER and J. SYMINGTON.

The remaining organs to be described all belong to the class of bodies known as *ductless glands*. Some of these, such as the lymphatic glands, have been described in the General Anatomy (Vol. I., Pt. 2) ; others, such as the solitary and agminated glands, the pituitary body and the pineal gland, with the viscera to which they are structurally connected. There remain to be noticed here the *spleen*, the *suprarenal capsules*, the *thymus gland*, the *thyroid body* with the *parathyroids*, and the small vascular nodules termed *carotid* and *coccygeal glands*.

THE SPLEEN.

The spleen (figs. 301 and 304) is a soft, highly vascular and easily distensible organ of a dark purplish colour. It is placed obliquely behind the stomach, its upper and inner end being in the posterior part of the epigastric region, while the lower, outer and larger portion is in the left hypochondrium. Its long axis, which on an

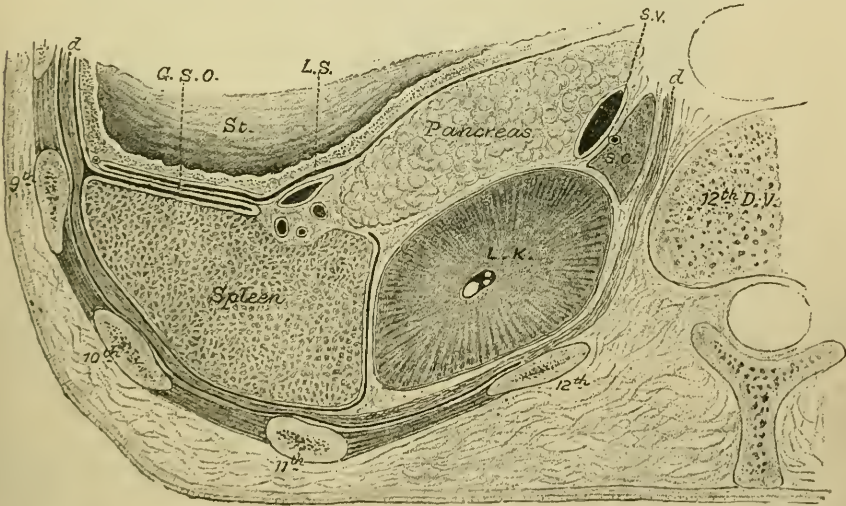

Fig. 301.—Horizontal section of the abdomen of an adult male at the level of the lower border of the body of the twelfth dorsal vertebra, seen from above. Nearly $\frac{1}{5}$. (J. S.)

L,K, left kidney ; *d.d*, diaphragm ; *s.c*, left suprarenal capsule ; *S.V*, splenic vein ; *St*, stomach ; *G.S.O*, gastro-splenic omentum ; *L.S*, lesser sac of the peritoneum.

average measures five to six inches, nearly corresponds with that of the lower ribs, and the organ usually extends from the level of the eighth rib above to the eleventh below. It is the largest of the ductless glands.

Surfaces and borders.—When hardened *in situ* the spleen has, according to Cunningham, the shape of an irregular tetrahedron, with its apex above and its base below. Its four surfaces are termed *phrenic*, *renal*, *gastric*, and *basal*. Of these the *phrenic* is large and convex, and lies against the diaphragm. In the greater part of its extent it looks upwards, backwards, and to the left, but near its upper end some-

what inwards. It is separated from the eighth, ninth, tenth, and eleventh ribs not only by the peritoneum and the diaphragm, but also in part of its extent by the left pleura and lung. The left lobe of the liver is occasionally found to extend backwards and to the left between the upper part of the phrenic surface and the diaphragm. The *renal* surface is generally flat, and narrower than the gastric, and does not reach so high as either the gastric or phrenic surfaces. Above, it generally touches the suprarenal capsule, and in the rest of its extent is in relation with the outer aspect of the left kidney. It looks inwards and downwards. The *gastric* surface is concave, and looks forwards and inwards. In the great part of its extent

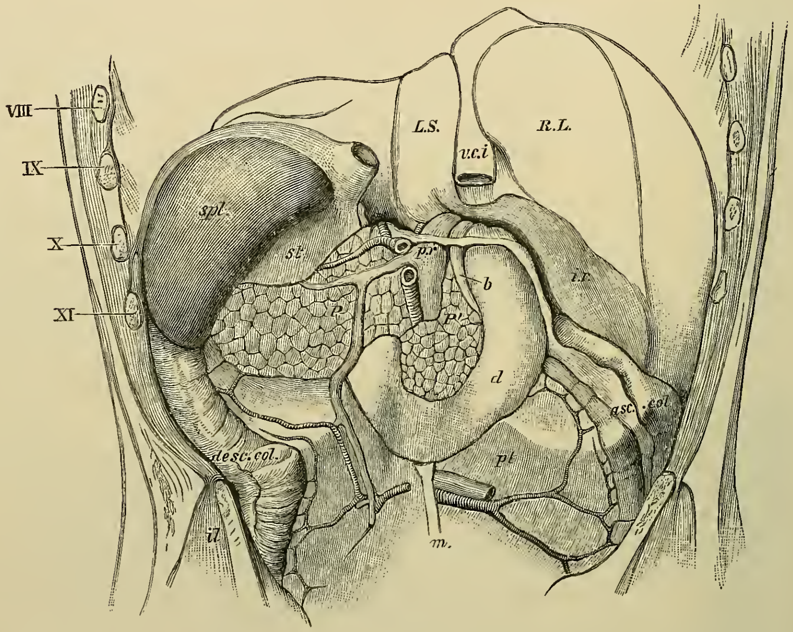

Fig. 302.—View of the abdominal viscera from behind, after removal of the spinal column, the whole of the posterior wall of the abdomen and the kidneys and suprarenal capsules, the peritoneum being left (this and the next figure are taken from Prof. His' models). $\frac{1}{3}$

P, pancreas ; *P'*, its head ; *d*, duodenum ; *st*, stomach ; *spl*, spleen ; *R.L.*, right lobe of the liver ; *L.S.*, Spigelian lobe ; *v.c.i.*, vena cava inferior ; *p.r.*, portal vein ; *b*, common bile duct ; *i.r.*, impression for the right kidney on the posterior surface of the liver ; the situation of the two kidneys is well shown by the corresponding impressions in the cast ; *asc. col.*, *desc. col.*, ascending and descending colon ; *pt*, back of the peritoneum ; *m*, line of attachment of the mesentery ; VIII, IX, X, XI, the corresponding ribs ; *il*, ilium.

it lies against the posterior surface of the stomach, but towards its lower end it touches the tail of the pancreas. This surface presents, parallel with and near its inner border (see fig. 304), a long fissure, or, more frequently, a series of depressions, termed the *hilum*, through which the vessels and nerves enter the spleen, and around which the peritoneum is reflected from the surface of the organ. The upper and inner extremity of the spleen is directed inwards, and reaches to within about an inch of the left side of the vertebral column, usually opposite the body of the eleventh dorsal vertebra. The lower and outer end is blunt, and presents a triangular area, which may be termed the *basal* surface (Cunningham). It lies against the tail of the pancreas, the splenic flexure of the colon and the costo-colic ligaments. Of

the borders of the spleen the *anterior*, situated between the gastric and phrenic surfaces, is the most prominent, and is usually marked near its lower end by one or two notches. Traced from its inner end, it is seen to curve outwards with the convexity of the curve upwards. This part of the anterior border reaches forwards and upwards between the diaphragm and the stomach nearly as high as the fundus of the stomach. Towards the left side this border turns downwards and somewhat forwards, being in close contact with the chest wall near the mid-axillary line and opposite the eighth, ninth, and tenth ribs. It generally terminates in a prominent angle. The *inner border* lies slightly internal to the hilum, and separates the gastric and renal surfaces. The *posterior* border is between the renal and phrenic surfaces. In some cases it is very well marked, dipping slightly inwards between the diaphragm

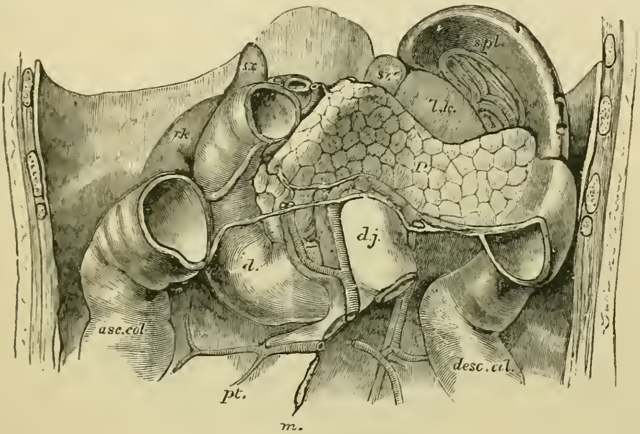

Fig. 303.—The pancreas and adjoining viscera from before. $\frac{1}{3}$

The liver, the stomach, the greater part of the small intestine, and the transverse colon have been removed. *P*, pancreas ; *d*, duodenum ; *d.j.*, duodeno-jejunal flexure ; above the duodenum, and between it and the head of the pancreas are seen the bile duct, portal vein, and hepatic artery ; *asc. col.*, *desc. col.*, ascending and descending colon ; *spl.*, spleen ; *r.k.*, *l.k.*, right and left kidneys ; *s.r.*, *s.r′*, right and left suprarenal capsules ; *pt*, peritoneum at the back of the abdominal cavity ; *m*, line of reflection of the mesentery ; the line of reflection of the transverse mesocolon is seen along the lower edge of the pancreas and crossing the duodenum.

and the kidney. It is inclined downwards and outwards opposite the lower border of the eleventh rib. A *lower* border separates the phrenic and basal surfaces.

Relation to peritoneum.—The spleen is almost entirely covered by peritoneum which is firmly connected with its capsule. It also gives attachment to two peritoneal folds—the gastro-splenic omentum and the lieno-renal ligament. The gastro-splenic omentum consists of two layers of peritoneum, which pass from the front of the hilum of the spleen forwards and outwards to the posterior surface of the stomach near its left border. If the outer of these layers be traced over the spleen it will be found to cover the gastric surface to the left of the hilum, the phrenic surface and the posterior part of the renal surface. It is then reflected on to the kidney, forming the posterior layer of the lieno-renal ligament. The inner layer of the gastro-splenic omentum is derived from the lesser sac, and is continued into the anterior layer of the lieno-renal ligament. Below, the two layers of the gastro-splenic omentum are continuous with the gastro-colic omentum. The splenic vessels pass to the spleen between the layers of the lieno-renal ligament.

The spleen varies in magnitude more than any other organ in the body; and this not only in different subjects, but, as may be ascertained by percussion, in the same individual under different conditions. On this account it is difficult or impossible to state what are its ordinary weight and dimensions. In the adult it may vary in weight from 100 grammes to 300 grammes, the average being about 170 grammes; it generally measures 120 to 130 mm. (five or six inches) in length, and the breadth of the phrenic surface is 70 to 80 mm.; its volume varies enormously, but usually does not exceed 200 to 300 cub. cent. After the age of forty the average weight gradually diminishes. In intermittent and some other fevers the spleen is much enlarged, reaching below the ribs, and often weighing as much as 18 lbs. to 20 lbs.

Accessory spleens.—Small detached roundish nodules are occasionally found in the neighbourhood of the spleen similar to it in substance. These are commonly named accessory or supplementary spleens (*splenculi, lienculi*). One or two most commonly occur, but a greater number, and even up to twenty-three have been met with. They are small rounded masses

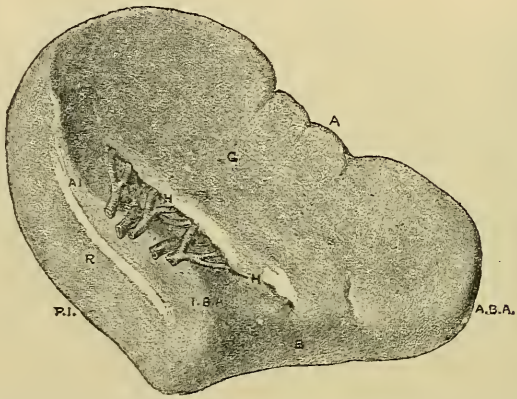

Fig. 304.—The spleen of an infant five days old, hardened in situ by the chloride of zinc method. Drawn from a model prepared by A. F. Dixon.

G, gastric surface; R, renal surface; B, basal surface; A, anterior border; A.I, antero-internal or inner border; P.I, posterior or postero-internal border; I.B.A, internal basic angle; A.B.A, anterior basic angle; H, hilum.

varying from the size of a pea to that of a walnut. They are usually situated near the lower end of the spleen, either in the gastro-splenic omentum or in the great omentum.

Spleen in the infant.—The spleen is relatively slightly larger in the new-born child than in the adult, but the peculiarities in the infant are mainly due to the large size of the liver and suprarenal capsule. The under surface of the left lobe of the liver is normally in contact with it at birth, and, according to Ballantyne, the hepatic area of the spleen is larger than any of the other surfaces. The same observer suggests that the renal surface in the new-born infant is more appropriately named the suprarenal, as this organ lies in contact with it and separates it in almost the whole of its extent from the kidney.

STRUCTURE OF THE SPLEEN.

The spleen has two membranous investments—a *serous coat* derived from the peritoneum, and a *fibrous coat* (*tunica propria*). The soft substance (*pulp*) of the organ is supported by a reticular framework of fibrous and muscular bands (*trabeculæ*).

The **serous coat** is thin, smooth, and firmly adherent to the tunica propria beneath. It closely invests the surface of the organ, except at the places of its reflection to the stomach and diaphragm, and at the hilum.

The **tunica propria** (fig. 305, A), much thicker and stronger than the serous coat, is whitish in colour and highly elastic. It is continuous with the trabecular

structure within. Along the hilum this coat is reflected into the interior of the spleen, in the form of large trabeculæ, supported and enclosed by which run the blood-vessels and nerves ; so that these are ensheathed by prolongations of the

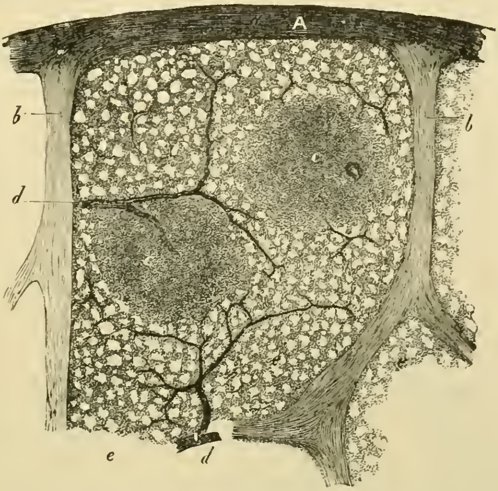

Fig. 305. —Vertical section of a small superficial portion of the human spleen (from Kölliker). Magnified with a low power.

A, peritoneal and fibrous covering ; *b*, trabeculæ ; *c c*, Malpighian corpuscles, in one of which an artery is seen cut transversely, in the other longitudinally ; *d*, injected arterial twigs ; *e*, spleen-pulp.

fibrous coat. These sheaths ramify with the vessels which they include, as far as their finer subdivisions, and are connected with numerous trabecular processes which pass into the interior from the whole inner surface of the fibrous coat. The arrangement of the sheaths and trabeculæ may be easily displayed in the spleen of

Fig. 306.—Thin section of spleen-pulp, highly magnified, showing the mode of origin of a small vein. (E.A.S.)

v, the vein, filled with blood-corpuscles, which are in continuity with others, *bl*, filling up the interstices of the retiform tissue of the pulp. At *p* the blood-corpuscles have been omitted from the figure, and the branched cells are better seen ; *w*, wall of the vein. The shaded bodies amongst the red blood-corpuscles are pale corpuscles.

the ox by pressing and washing out the pulp from a thick section ; and then they are seen to form a close reticulation through the substance. Thus, the fibrous coat, the sheaths of the vessels, and the trabeculæ, all of a highly elastic nature, constitute a distensible framework, which contains in its interstices or areolæ the

red pulp. These fibrous structures are composed of interlaced bundles of areolar tissue containing a large amount of fine elastic tissue, and a few plain muscular fibre-cells. In the spleen of the pig, the dog, and the cat, and to a smaller extent in that of the ox and sheep, there is a far more abundant admixture of muscular tissue, and this tissue exhibits a regular rhythmic contractility (Roy).

The **pulp** of the spleen is of a dark reddish-brown colour: when pressed out from between the trabeculæ it resembles grumous blood, and, like that, acquires a brighter hue on exposure to the air. In fact, what is thus pressed out from the dead spleen is mainly clotted blood.

When a thin section which has been treated with dilute solution of potash is examined under the microscope the pulp is seen to be everywhere pervaded

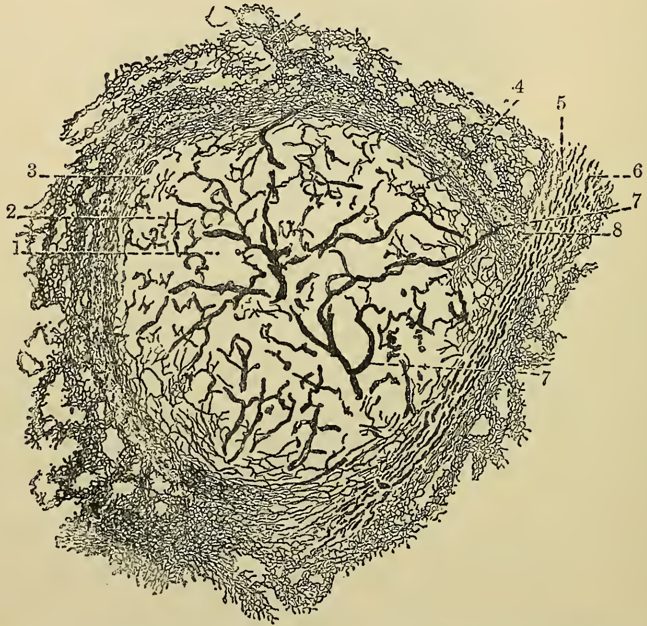

Fig. 307.—Reticulum of spleen pulp shown by silver-chromate method. The capillaries of a Malpighian corpuscle are also seen. (Oppel.)

1, Malpighian corpuscle ; 2, part of its reticulum ; 3, condensed reticulum around margin of corpuscle ; 4, more open tissue outside this ; 5, 6, connective tissue of artery ; 7, capillaries of Malpighian corpuscle ; 8, reticulum of pulp immediately investing arteriole.

by a reticulum of fine fibres continuous with the tissue of the trabeculæ. These fibres are in the natural condition covered over and concealed by branched connective-tissue corpuscles, which are of various forms and sizes ; in some parts little but the intercommunicating branches remaining, in other parts the cells being larger and flatter and in closer connection (fig. 306, *p*). These corpuscles, which may be termed the *reticular cells of the pulp*, contain each a round or oval nucleus, like connective-tissue cells generally : and, in teased-out preparations of the fresh spleen substance it is not uncommon to find within them yellowish pigment granules of various sizes. In the young subject the nuclei of many of these cells have been noticed to be multiple, or to be beset with prominences as if budding. The interstices between the sustentacular cells are, in sections of the hardened organ, always found to be occupied by blood (fig. 306, *bl*), white corpuscles occurring in rather larger proportion than in ordinary blood, especially in the neighbourhood of

the Malpighian corpuscles to be immediately described. In close relation to the branched or flattened cells of the pulp, and occupying some of the smaller interstices between them, rounded, unbranched cells are seen (*spleen-cells*), larger than white blood-corpuscles, but otherwise much resembling them. These cells are amœboid, and, like the fixed cells of the pulp, often contain both red blood corpuscles in various stages of disintegration, and clumps of pigment granules. Some observers have noted the presence of nucleated red corpuscles (similar to those found in marrow) both in the splenic pulp and in the blood of the splenic vein.

Böhm and v. Davidoff describe tubular spaces within the pulp of the human spleen, lined by a "rodded" epithelium like that in the convoluted tubes of the kidney, but they leave the nature of these spaces unelucidated.

Blood-vessels.—The splenic artery and vein, alike remarkable for their great proportionate size, having entered the spleen by six or more branches, ramify in its interior, enclosed within the trabecular sheaths already described.

The smaller branches of the arteries have an adventitia derived from the trabeculæ, and pass into the proper substance of the spleen, dividing into small

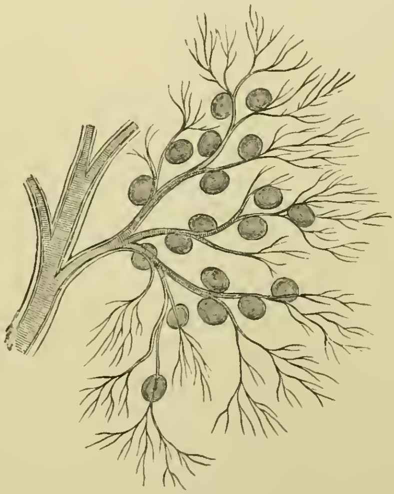

Fig. 308.—Small artery from the dog's spleen with Malpighian corpuscles attached. 10 Diameters. (Kölliker.)

tufts of arterioles arranged in pencils (fig. 308). But before they thus terminate, the adventitious fibrous coat which is prolonged over them from the trabeculæ becomes transformed into lymphoid tissue, which forms a comparatively thick sheath along each. This lymphoid sheath is abruptly dilated here and there into small oval or spheroidal enlargements, measuring on an average 0·36 mm. in diameter, but varying in size from much smaller than this up to 1 mm., and closely resembling the lymphoid follicles met with in the intestine and elsewhere. These lymphoid expansions may be seen on the surface of a fresh section of the organ as light-coloured spots scattered in the dark substance composing the pulp, and have been long noticed and described as the **Malpighian corpuscles** of the spleen (fig. 305, *c c*, fig. 308). In some cases the corpuscle is developed upon one side only of the arterial wall, upon which it then appears to be sessile ; whilst in other instances—and this is the most frequent in the human subject—the expansion takes place all round the circumference of the vessel, by which it then appears to be pierced. In either case the artery sends off radiating branches to be distributed in the Malpighian corpuscle.

As just stated, the Malpighian corpuscles are localised expansions of the lymphoid tissue of which the external coat of the smaller arteries of the spleen is formed, and have apparently been produced by increased multiplication of lymph-cells at the spots in question. The reticulum of the tissue is comparatively open, being almost absent towards the centre of the corpuscle : at the confines it becomes closer ; there is, however, no distinct boundary separating it from the retiform tissue of the pulp. The meshes are densely packed with lymphoid corpuscles, and the tissue is traversed by capillaries.

The small arteries, after leaving the Malpighian corpuscles, terminate in capillary vessels, which soon lose their tubular character, the cells which compose their wall becoming partially separated from one another by elongated clefts ; those at the extremity of the capillary have branching processes and are united by these with the branched connective-tissue cells of the pulp. In this manner the blood can flow directly into the interstices of the pulp tissue. The veins, which form a network of intercommunicating spaces within the pulp, commence in the same manner as the capillaries terminate ; that is to say, the layer of flattened cells which lines and mainly composes their walls, on being traced back, loses its epithelioid character, and the cells, becoming thickened and spindle-shaped and their nuclei prominent, are found to be separated here and there from each other, and to be connected by processes with the cells of the pulp (fig. 306). The small veins take a different course from the arteries, for they soon pass to the trabeculæ and are conducted upon and within these, freely joining and anastomosing ; whereas the arteries appear to have few or no anastomoses within the substance of the organ.

The small veins within the pulp of the human spleen often exhibit peculiar transverse markings. These are produced by fine elastic fibres of the reticulum, which encircle the vessels. Structures which have been described as "ellipsoids," which are in fact condensations of the reticular tissue of the spleen pulp not loaded with leucocytes as in the Malpighian corpuscles, are often found encircling the terminations of the arterioles. They are stated by Müller (bird) and Whiting (cat) to be surrounded by a special vascular sinus, but this is denied for the cat by Carlier.

From the description above given, it would appear that the blood in passing through the spleen is brought into immediate relation with the elements of the pulp, and no doubt it undergoes important changes in the passage ; in this respect resembling the lymph as it passes through the lymphatic glands. Two modifications which are probably effected in it may be here pointed out. In the first place the lymphoid tissue ensheathing the arteries, together with that composing the Malpighian corpuscles, would appear like the same tissue in the lymphatic glands, and other parts, to be the seat of the production of pale blood corpuscles. At the circumference of this tissue, these may pass into the interstices of the pulp, and so into the blood. It is found, in fact, that the blood of the splenic vein is extremely rich in pale corpuscles. In the second place, red blood-corpuscles may be taken up by the pulp-cells, their colouring matter being transformed into pigment. The splenic cells have, indeed, been noticed, when examined on the warm stage, to take red corpuscles into their interior. Finally, if it be the case that nucleated red corpuscles occur normally in the spleen, it is probably also a seat of formation of coloured blood corpuscles.

The **lymphatics** of the spleen form two systems, a *trabecular* and a *perivascular*. The vessels belonging to the former system run in the trabeculæ and are in communication with a superficial network in the capsule. The perivascular lymphatics take origin in the interstices of the lymphoid tissue which ensheaths the smaller arteries, and which forms the Malpighian corpuscles ; they do not, therefore, at first form distinct vessels. When these are seen they commonly run in pairs, one on either side of an artery, uniting over it by frequent anastomoses, and sometimes

partially or wholly enclosing it. At the hilum the two sets of lymphatics join one another and proceed along with the main blood-vessels, and ultimately pass into lymphatic glands at the back of the abdomen.

The **nerves**, derived from the solar plexus, surround and accompany the splenic artery and its branches. They are most probably distributed to the vessels and plain muscular tissue of the framework.

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SUPRARENAL CAPSULES.

The suprarenal bodies or capsules (*capsulæ atrabilariæ seu renes succenturiati* of old anatomists), also frequently termed "adrenals," are two flattened bodies, each of which surmounts the corresponding kidney (fig. 309). They are both

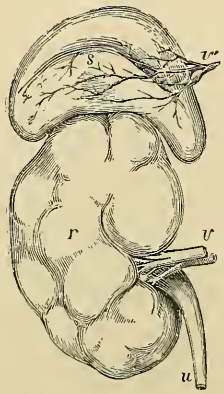

Fig. 309.—Front view of the right kidney and suprarenal body of a full grown fœtus. (Allen Thomson.)

This figure shows the lobulated form of the fœtal kidney, *r*; *v*, the renal vein and artery; *u*, the ureter; *s*, the suprarenal capsule, the letter is placed near the sulcus in which the large veins (*v'*) are seen emerging from the interior of the organ.

situated in the epigastric region, one on each side of the vertebral column. They differ from one another in shape and also in their relations. The **right capsule** has a flattened triangular form, one surface called *anterior* looks forwards and outwards, and the other, the *posterior*, backwards and inwards, while the angles are directed upwards, downwards and outwards. The *anterior surface* has a furrow, called the *hilum*, which passes horizontally a little below the upper border and vertically near the inner border. At the union of these two parts of the fissure the capsular vein emerges from the organ. The area above and internal to the fissure is depressed and forms about one-third of the anterior surface. The inner part of this area lies behind the inferior vena cava, and the upper part is in direct contact with the liver. The outer and larger

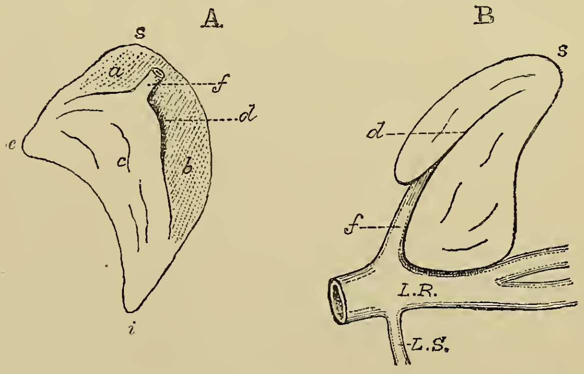

Fig. 310.—Anterior surface of the suprarenal capsules, modified from Rolleston. (J. S.)

A, right capsule, *s*, *e*, *i*, its superior, external and inferior angles; *a*, area in direct contact with liver; *b*, area behind inferior vena cava; *c*, area, below and external to the fissure, covered by the peritoneum and the liver except near the inferior angle where it comes in contact with the duodenum; *d*, fissure on anterior surface; *f*, vein.

B, left capsule. *s*, its superior angle; *d*, fissure on anterior surface; *f*, vein; *L. R*, left renal vein; *L.S*, left spermatic vein.

portion of the anterior surface is covered by the peritoneum, which separates it from the liver, except a small area near the inferior angle, which sometimes lies against the duodenum. The *posterior surface* also has a depression dividing it into two parts, one of these, the upper and larger, lies against the diaphragm, and is bounded below by an elevation projecting into the groove between that muscle and the kidney; the lower and smaller area is in contact with the kidney.

The **left suprarenal capsule** is slightly larger than the right. It does not project so much above its corresponding kidney, but is prolonged downwards along the upper half of its inner border. Looked at from the front, its outline is crescentic, the concavity of the crescent being directed downwards and outwards towards the kidney. The *anterior surface* lies in contact with the upper end of the renal surface of the spleen and the stomach near its cardiac orifice, while its lower half is crossed by the pancreas and the splenic vessels. It has a groove passing

downwards and forwards, at the lower end of which the suprarenal vein emerges. The *posterior surface* is divided into two parts by a prominent vertical ridge, the

Fig. 311.—SECTION OF THE SUPRARENAL BODY. (Allen Thomson.)

A vertical section of the suprarenal body of a fœtus, twice the natural size, showing the lower notch by which it rests on the summit of the kidney (*r*), and the anterior notch by which the suprarenal vein (*v*) issues, together with the distinction between the medullary and cortical substance.

area mesial to the ridge looking inwards and backwards and resting upon the left crus of the diaphragm and the lateral area outwards as well as backwards against the kidney.[1]

The suprarenal capsules measure from $1\frac{1}{4}$ in. to $2\frac{1}{2}$ in. (30 mm. to 60 mm.) from above downwards and about $1\frac{1}{4}$ in. (30 mm.) from side to side; their thickness is from $\frac{1}{6}$th in. to $\frac{1}{4}$ in. (4 mm. to 6 mm.), the left being usually thicker than the right. The weight of each in the adult is about 1 drachm (4 grammes), the left being slightly the heavier. They are nearly as large at birth as in adult life.

Structure.—Besides a covering of areolar tissue mixed frequently with much

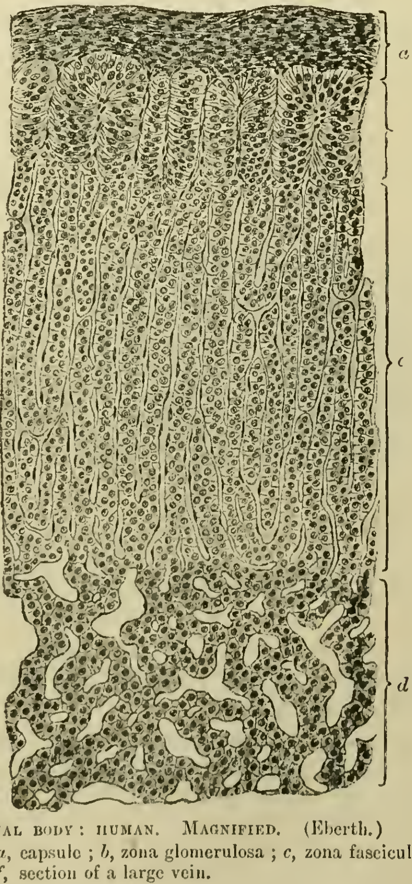

Fig 312.—VERTICAL SECTION OF SUPRARENAL BODY: HUMAN. MAGNIFIED. (Eberth.)
1, cortical substance; 2, medullary substance: *a*, capsule; *b*, zona glomerulosa; *c*, zona fasciculata; *d*, zona reticularis; *e*, groups of medullary cells; *f*, section of a large vein.

Fig. 313.—SECTION OF THE CORTEX OF THE DOG'S SUPRARENAL. (Böhm and v. Davidoff.)
a, fibrous covering; *b*, zona glomerulosa; *c*, zona fasciculata; *d*, zona reticularis.

[1] The above description is based largely upon the account of these organs given by H. D. Rolleston (Journal of Anatomy and Physiology, vol. xxvi).

fat, the suprarenal capsules have a thin fibrous investment. On the exterior their colour is yellowish or brownish-yellow. When cut into (fig. 311) they are seen to consist of two substances: one, *external* or *cortical*, of a deep yellow colour, firm and striated, and forming the principal mass of the organ; the other, *internal* or *medullary*, in the adult of a dark brownish-black hue, and so soft and pulpy that some anatomists have erroneously described a cavity within it.

The **fibrous coat** (figs. 312, 313, *a*), which is distinguishable into an outer looser and an inner firmer part, is so intimately connected with the deeper parts that it cannot be removed without lacerating the subjacent structure. Its deeper layers contain plain muscular cells, at least in some animals: it is continuous with the septa which enter into the formation of the substance of the organ.

The **cortical part** of the suprarenal body, examined in a section with a low magnifying power (fig. 312, 1; fig. 313), is seen to consist of a fibrous stroma, in which are embedded column-like, intercommunicating groups of cells (*c*). The groups measure on an average $\frac{1}{700}$th inch (·036 mm.) in diameter, and are arranged vertically to the surface of the organ. In the deepest part of the cortex, however, the colour is darker, and the columnar arrangement is lost, the stroma being more equally distributed (*d*); and immediately beneath the fibrous coat there is another narrow zone in which the stroma encloses what in section look like rounded or oval spaces occupied by groups of cells, which are really the outer ends of the columnar groups above mentioned (*b*). These inner and outer layers have been named respectively *zona reticularis* and *zona glomerulosa*, and the term *zona fasciculata* is applied to the main part (*c*); but the transition from one of these parts to another is in man not sudden nor indicated by any sharp line of demarcation.

The cells which form the groups and columns of the cortical substance are

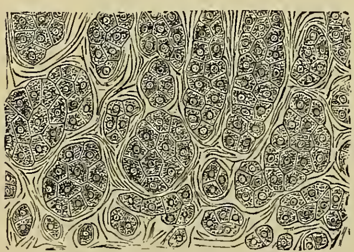

Fig. 314.—Cells and cell-groups from the outermost layer of the cortical substance of the suprarenal body. Highly magnified. (Eberth.)

Fig. 315.—A small portion of the medullary part of the suprarenal capsule of the ox (Eberth.) Highly magnified.

polyhedral in form (fig. 314): their protoplasm is finely reticular, and not unfrequently contains yellowish oil globules. The cells vary from ·0125 mm. to ·02 mm. in diameter.

In some animals (horse, dog, cat), the spaces of the zona glomerulosa are occupied by regularly arranged long columnar cells, set around a sort of lumen, and looking not unlike part of a glandular tube (fig. 313, *b*). In man, however, most of the cells of this part are polyhedral, like those of the other zones.

The **medullary part** (fig. 312, 2) of the suprarenal capsule is marked off from the cortical part by a layer of loose connective tissue. In the thinner parts of the adult organ there is no medullary part, and the layer of connective tissue referred to is found separating the deep surfaces of two opposed portions of the cortical part; but in the young state the distinction of cortical and medullary portions probably

extends throughout the whole gland. The medullary part is pervaded by large venous capillaries, which receive the whole of the blood which has passed through the organ. These venous capillaries are supported by the fibrous stroma, which also contains, especially in man, a number of bundles of plain muscular cells disposed parallel to the course of the larger veins, and forming a complete investment to the issuing suprarenal vein (v. Brunn). The general arrangement of the stroma is reticular ; in its meshes are enclosed groups of cells (fig. 315), which differ from those of the cortex in being more irregular in form, larger in size, of a clearer aspect, and destitute of oil-globules. They are frequently highly vacuolated. Moreover they become stained of a deep brown colour by solutions of bichromate of potash, whereas the cortical cells are but slightly tinged by that re-agent.

In some animals the medullary cells contain a large amount of reddish-brown pigment, which marks the medulla off sharply from the cortex, but this is not generally the case in the human subject, the deep colour of the medulla being chiefly due to the blood within its numerous vessels.

Varieties.—One or both capsules may be absent, although this is very rarely the case. Accessory suprarenal capsules are occasionally met with varying in size from a pin's head to that of a large pea. The smaller ones have no medullary substance, but the large ones possess a medulla (Rolleston). The accessory capsules are generally found near or upon the capsule itself and united to it by connective tissue. Sometimes they are partially embedded in the kidney or liver, and Marchant has found them in the broad ligament of the uterus, and Schmorl on the spermatic vessels near the inguinal canal.

Arteries and veins.—The suprarenal bodies receive arteries from three sources, viz., from the *aorta*, the *phrenic* and the *renal* arteries. All these arteries break up into small branches before entering the capsule. The veins, which pass out from the centre, are usually united into one for each organ. The right vein enters the inferior vena cava immediately, while the left, after a longer course, terminates in the left renal vein.

The small arteries, entering from the surface, run in the septa parallel to the columns, frequently anastomosing together, and surrounding each group of cells with a fine capillary network. From these capillaries the blood is continued into the medulla, where it is collected into the large venous capillaries already mentioned. The chief efferent vein emerges at the hilum. According to Pfaundler, none of the vessels in the suprarenals have any coat other than the endothelium.

Lymphatics run in the trabeculæ of the cortical substance and are connected with cleft-like spaces between the trabeculæ and the cell-columns, and even with fine clefts between the cells within the columns (Klein). They communicate with efferent valved lymphatics both in the fibrous coat and in the medulla, where they are very numerous, forming an especially close plexus around the central vein.

Nerves.—The nerves, which are exceedingly numerous, are derived from the *solar plexus* of the sympathetic and from the *renal plexuses*. According to Bergmann some filaments come from the *phrenic* and *pneumo-gastric* nerves. They are made up mainly of medullated fibres of different sizes, and they have many small ganglia upon them before entering the organ. The nerves are especially numerous on the lower half and inner border. They ramify between the cells of the cortex, where they are especially abundant in the zona glomerulosa. In the medulla they are connected with numerous small ganglion-cells, and are distributed to the blood-vessels and amongst the glandular cells.

Function.—Removal of the suprarenal bodies in animals is speedily followed by symptoms of extreme muscular prostration and, within a very few days, by death (Brown-Séquard, 1856). Disease of the organs is usually accompanied by the appearance of bronzed patches on various parts of the skin and mucous membranes (Addison, 1855), and the symptoms in ad-

vanced disease are similar to those resulting from removal. The watery extract of the medulla of the capsules contains a (non-proteid) substance which produces when injected even in minute quantities into the blood-vessels of an animal, a great augmentation of the contraction of the muscular tissue of the heart and arteries, and prolongs the contractions of the skeletal muscles (Oliver and Schäfer, 1894).

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THE THYMUS GLAND.

The thymus gland or body is a temporary organ which reaches its greatest size at about the end of the second year of life, after which period it ceases to grow, and is gradually reduced to a mere vestige. Its function is not fully understood, although it is probable that it is in some way connected with the elaboration of the blood in infancy. When examined in its mature state in an infant under two years of age, it appears as a narrow elongated glandular-looking body, situated partly in the thorax, and partly in the lower region of the neck (fig. 316) : below, it lies in

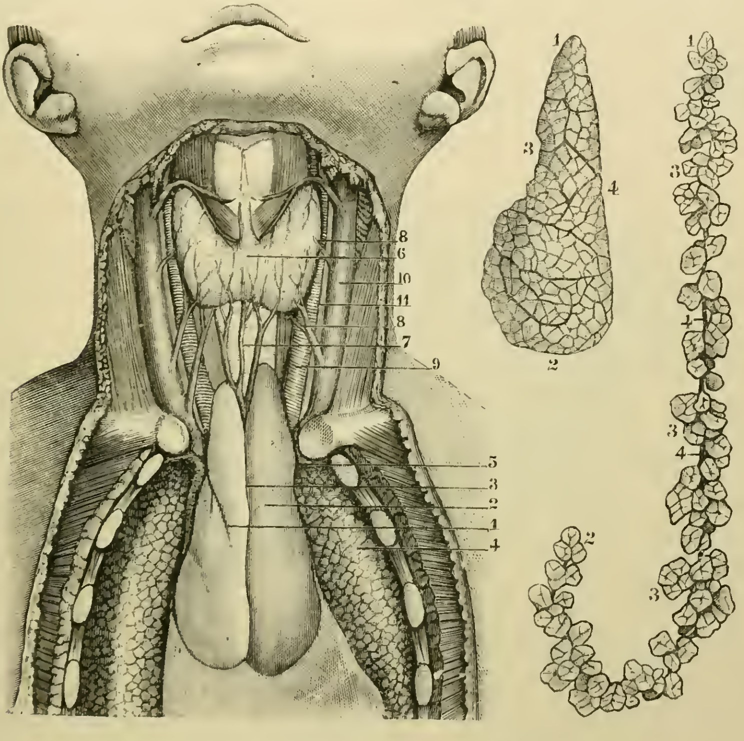

Fig. 316.—The thymus in a child of six months. (Sappey.)

A. Situation, form and relations of the gland. 1, right lobe ; 2, left lobe ; 3, median furrow ; 4, lung, somewhat everted ; 5, internal mammary vein ; 6, thyroid body ; 7, inferior, 8, middle thyroid veins ; 9, common carotid artery ; 10, internal jugular vein ; 11, pneumo-gastric nerve. B. Right lobe of the thymus after removal of its envelope ; 1, its apex ; 2, its base ; 3, thin outer border ; 4, thick inner border. C. The gland unravelled, showing the lobules, 3, grouped around a central cord ; 4, the central cord or strand of connective tissue, connecting the lobules.

the superior and anterior mediastinal spaces close behind the sternum as far down as the fourth rib-cartilage, and in front of the great vessels and pericardium ; above, it extends upwards upon the trachea in the neck as high as the lower border of the thyroid body, being covered by the sterno-hyoid and sterno-thyroid muscles. Its colour is greyish, with a pinkish tinge ; its consistence soft and pulpy, and its surface appears distinctly lobulated. It consists of two *lateral lobes*, which touch each other along the middle line, and are of a nearly symmetrical long pyramidal form, though generally unequal in size, sometimes the left, and at other times the right lobe being the larger of the two. An *intermediate lobe* often exists between the two lateral ones, and occasionally the whole body forms a single mass.

Externally the gland is in contact with the pleura, near the internal mammary artery, and higher up (in the neck), with the sheath of the carotid artery. The dimensions of the thymus vary according to its stage of development. At birth it measures rather more than two inches (60 mm.) in length, an inch and a half (37 mm.) in width at its lower part, and about one quarter or one third of an inch (6—8 mm.) in thickness. Its weight at this period was found by Testut, on an average of twenty cases, to be 5 grammes.

At puberty the thymus is generally reduced to a mere vestige which has entirely lost its original structure. and consists of brownish tissue occupying part of the superior mediastinum. Occasionally it is still found in good condition at the twentieth year; but generally only traces of it remain at that time, and these are rarely discoverable beyond the twenty-fifth or thirtieth year.

Structure.—The lateral lobes of the thymus gland are each invested by a thin capsule of areolar tissue, which sends partitions into the gland between the lobules: on its outer surface the capsule is covered by a layer of flattened cells. Each lobe

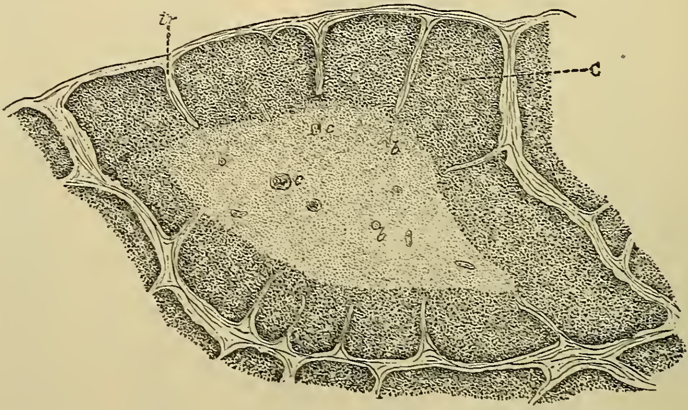

Fig. 317.—From a section of the thymus of a child. (E. A. S.)

c, cortex of a lobule partly separated into nodules by the trabeculæ, *tr.*; *b*, *b*, blood-vessels and *c*, *c*, connective tissue corpuscles in the medulla.

consists of numerous polyhedral *lobules*, connected by a more delicate intervening areolar tissue. These primary lobules are made up of a number of small nodules or follicles (fig. 317), one to two millimeters in diameter. Each follicle is composed of a central part or *medulla*, and an external larger part or *cortex*. The cortex is in many respects similar in structure to an ordinary lymphoid follicle, such as those of the tonsils or of Peyer's patches in the intestine: consisting, like these, of retiform tissue composed of a fine reticulum of fibres, the meshes being filled with lymphoid cells (*thymus corpuscles*). At the surface of the follicle the retiform tissue is somewhat closer, so as to form a species of capsule for it. In some animals these capsules completely enclose the follicles, but in others, including man, several follicles may be united towards the centre of the lobule (see fig. 317), which is then commonly of softer consistence than the other parts, and apt to break down if not perfectly fresh, so as to give the deceptive appearance of a central cavity.

In the medulla, the retiform tissue is coarser and the lymphoid cells fewer; but it contains here and there nests of cells which have a concentric structure, and are known as the *concentric corpuscles of Hassall.* They vary in size from 0·025 mm. to three times that diameter, or more; the larger ones (compound corpuscles) often contain smaller ones in their interior (fig. 318).

Each nest is composed of an envelope of keratinized epithelium-like cells enclosing a central mass, formed of one or more granular cells. Cells like those in the centre of the nest are also found, unenclosed, in the retiform tissue of the follicle, and occasionally attain a large size (giant-cells). The concentric corpuscles are vestiges of the original epithelial tube which is found in the developing thymus (see Vol. I., Pt. 1, p. 111). According to some authorities the thymus corpuscles are also of epithelial (*i.e.*, hypoblastic) origin, and are not derived as has usually been believed, from the surrounding mesoblastic tissue. Small portions of thymus tissue are constantly found, according to Kohn, in association with the thyroid and para thyroids. Schaffer describes in the thymus nucleated red blood corpuscles like those met with in bone-marrow.

Fig. 318.—Part of the medulla of a thymus gland showing the reticulum, the lymphoid cells or thymus corpuscles and two concentric corpuscles. (Cadiat.)

The retrogressive development of the gland is accompanied by an increase in the interstitial connective tissue, which also invades the follicles. In this tissue plasma-cells become accumulated, and then appear to be eventually transformed into fat-cells, the normal structure of the thymus becoming gradually obliterated. It has been shown, however, by Waldeyer, that even in advanced age not only can the original shape of the thymus be distinctly made out, but that in addition there are constantly to be found traces of its original structure in the form of small masses of thymus corpuscles and even of concentric corpuscles.

Vessels and Nerves.—The **arteries** of the thymus are derived from various sources, viz., from the *internal mammary*, the *inferior* and *superior thyroid*, the *subclavian* and *carotid arteries*. Their branches penetrate to the follicles, where they form a plexus which surrounds the cortex and from which capillaries converge towards the medulla. In some animals these vessels loop back towards the cortex, but in others they open into an inner vascular circle which lies just within the boundary of the medulla. The **veins,** for the most part, open into the *left innominate vein.*

The **lymphatics** are large. According to the observations of His on the calf, the larger blood-vessels passing to the centre are each accompanied by two or more lymphatic trunks. These arise from an interlobular plexus, which again is in connection with vessels which surround and enclose the individual follicles without penetrating them (as in those of the intestine).

The **nerves** are very minute. Haller thought that they were partly derived from the phrenic nerves, but according to Cooper, no filaments from these nerves go into the gland, although they reach the investing capsule, as does also a branch from the descendens hypoglossi. Small filaments, derived from the *pneumo-gastric* and *sympathetic nerves*, descend, on the thyroid body, to the upper part of the thymus. Sympathetic nerves also reach the gland along its various arteries.

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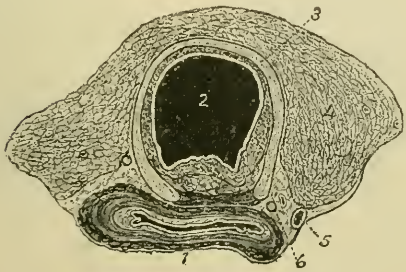
THE THYROID BODY.

The thyroid body is a highly vascular organ consisting of two *lateral lobes* generally united towards their lower ends by a transverse portion named the *isthmus*. Viewed as a whole it is convex on its external and anterior aspects forming a rounded projection upon the trachea and larynx. It is covered by the sterno-hyoid, omo-hyoid, and sterno-thyroid muscles, the last-mentioned being in close contact with the lateral lobes. The sterno-cleido-mastoid muscles also overlap it. Its deep surface is concave where it rests against the trachea and larynx, and external to these structures and the recurrent laryngeal nerves its lateral lobes extend backwards to the sides of the pharynx and œsophagus. In consequence of the deviation of the œsophagus to the left side the lower end of the left lateral lobe lies slightly in front of that structure. The lateral lobes also pass outwards in front of the common carotid arteries, the carotid sheaths intervening. Each lateral lobe is somewhat conical in form with the apex upwards, and extends from the fifth or sixth ring of the trachea to the side of the thyroid cartilage of which it covers the inferior cornu and adjacent portion of



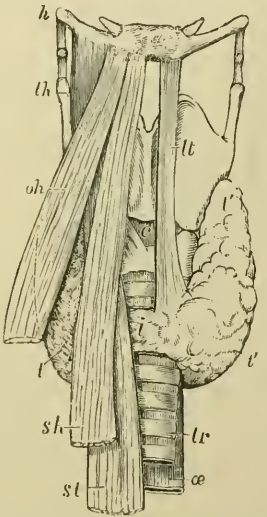


Fig. 319.—Horizontal section of trachea, œsophagus, and thyroid body. (J. S.)

1, œsophagus ; 2, cavity of trachea ; 3, cartilaginous ring of trachea ; 4, thyroid body ; 5, inferior thyroid artery ; 6, recurrent laryngeal nerve.

Fig. 320.—Sketch showing the form and position of the thyroid body. (Allen Thomson.) One half the natural size.

The larynx and surrounding parts are viewed from before ; on the right side the muscles covering the thyroid body are retained, on the left side they are removed ; *h*, hyoid bone ; *th*, right thyro-hyoid muscle ; *o h*, omo-hyoid ; *sh*, sterno-hyoid ; *st*, sterno-thyroid ; *c*, crico-thyroid membrane ; *tr*, trachea ; *œ*, œsophagus ; *t*, right lobe of the thyroid body ; *t'*, the left lobe ; *i*, the isthmus ; *lt*, the fibrous or muscular band termed levator thyroideæ, which is more rarely found in the middle line or to the right side, and which existed in the case from which the figure was taken.

the ala. The transverse portion or isthmus commonly lies across the second, third and fourth rings of the trachea, but is very inconstant in size, shape, and position. From the upper part of the isthmus or from the adjacent portions of one of the lobes a slender conical process called the *pyramid* or *middle lobe* often proceeds upwards to the hyoid bone to which it is attached by fibrous or muscular tissue (fig. 316). The thyroid gland is connected to the trachea and larynx by fibrous tissue so that it follows the movements of these organs. In front the pretracheal fascia extends

from the isthmus and adjacent portions of the lateral lobes upwards to the front of the cricoid cartilage and the lower border of the thyroid cartilage, forming a somewhat indistinct *anterior ligament* of the gland. Further, each lateral lobe is attached by a firm band of fibrous tissue, the *lateral ligament*, to the side of the cricoid cartilage and the first two or three rings of the trachea.

Size, weight, and colour.—Each lateral lobe measures about two inches (50 mm.) in length, an inch and a quarter (30 mm.) in breadth, and three quarters of an inch (18 mm.) in thickness at its largest part which is below its middle; the right lobe is usually a little wider and longer than the left. The isthmus measures nearly half an inch (12 mm.) in breadth and from a quarter to three quarters of an inch in depth.

The weight of the thyroid body is ordinarily rather more than an ounce (30 to 40 g.). It is generally larger in females than in males, and appears in many of the former to undergo a periodic increase about the time of menstruation. It varies a good deal in size and occasionally undergoes enormous enlargement.

Its colour is usually of a dusky brownish red, but sometimes of a yellowish hue.

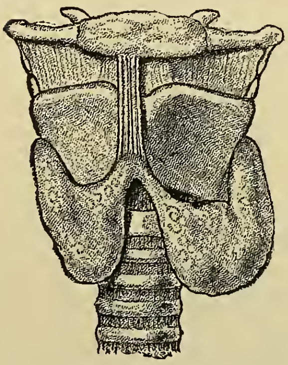
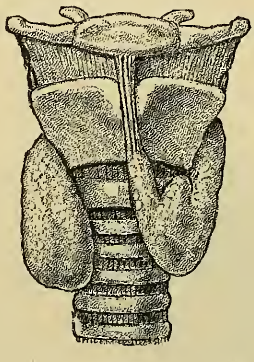
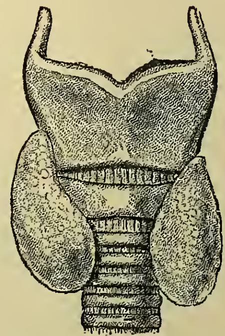




Fig. 321.—A THYROID GLAND SHOWING BIFURCATION OF THE LOWER END OF PYRAMID PROCESS, ONE PART GOING TO EACH LATERAL LOBE. (After C. F. Marshall.)

Fig. 322.—A THYROID GLAND WITH PYRAMIDAL PROCESS ATTACHED TO LEFT LOBE OF GLAND, ISTHMUS ABSENT. (After C. F. Marshall.)

Fig. 323.—A THYROID GLAND, WITH BOTH PYRAMIDAL PROCESS AND ISTHMUS ABSENT. (After C. F. Marshall.)

Varieties.—As a rule the two lateral lobes are approximately equally well developed, but occasionally they are very unequal in size and in rare cases one lateral lobe may be entirely absent. The isthmus varies greatly in size and not unfrequently it is absent or fused with one or other of the lateral lobes. Observers differ considerably as to the frequency with which a pyramidal process occurs. Thus Streckeisen met with it in 104 out of 153 cases, or nearly 68 per cent., while Marshall only found it in 24 out of 60 cases, or 40 per cent. It is usually attached below to the isthmus on the left side of the median plane, but it may join one of the lateral lobes, and above it is connected with the hyoid bone. Out of the 104 specimens in which the pyramidal process was present 55 were glandular up to the hyoid bone, in 12 the process was connected to that bone by fibrous tissue, and in 2 by muscle. The muscular fasciculi which are occasionally found to descend from the hyoid bone to the thyroid gland or its pyramidal process are known as the *levator glandulæ thyroideæ* (fig. 320). The fibres are most frequently derived from the thyro-hyoid muscle, but occasionally they are independent. In one of Marshall's cases there were two pyramidal processes, while in another a single process divided into two parts, one for each lateral lobe. Accessory thyroids may be formed by transverse division of the pyramidal process into several separate masses, more rarely they are found in relation with the lateral lobes. Small glandular masses, resembling in structure the thyroid are also frequently found in front of and above the hyoid bone.

Structure.—The texture of this organ is firm, and to the naked eye appears coarsely granular. It is invested by a thin transparent layer of dense areolar tissue

which connects it with the adjacent parts, and imperfectly separates its substance into small lobules of irregular form and size.

When the organ is cut into, a yellow glairy fluid (*colloid*) escapes from the cut surface. Imbedded in its substance are multitudes of closed *vesicles* (fig. 324), which are held together in groups or imperfect lobules by areolar tissue. The size of the vesicles varies from ·045 mm. to 1· mm., so as to be visible to the naked eye. They are spherical, polyhedral, or flattened in shape. The wall of each vesicle consists of a simple layer of cubical or columnar epithelium-cells which, according to Langendorff, are of two kinds, viz.:—those which are actually secreting the material of the contents of the vesicles (*colloid cells*) and others (*reserve cells*) which may take the

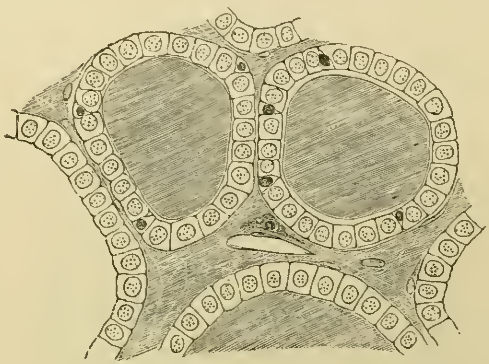


Fig. 324.—Section of the thyroid gland of a child. (E. A. S.)

Two complete vesicles and portions of others are represented. The vesicles are filled with colloid which, in this case, also occupied the interstitial spaces. In the middle of one of the spaces a blood-vessel is seen cut obliquely, and close to it is a plasma-cell. Between the cubical epithelium cells, smaller cells like lymph-corpuscles are seen here and there.

place of some of the colloid cells which become detached or mingled with the secretion. Both Langendorff and Hürthle agree in stating that the secretion is formed partly by exudation from the cells an partly by the complete transformation of some of the cells into colloid substance. According to Baber there is no basement membrane to the vesicles.

The vesicles may contain, besides the characteristic yellow glairy fluid, detached epithelium-cells, white blood-corpuscles which seem to have migrated into the cavities, and also red blood-corpuscles in various stages of disintegration and decolourization, but whether these last are accidental or normal constituents is still undecided.

In the interstitial connective tissue of the gland there occur a number of cells similar to the "plasma-cells" of Waldeyer ("parenchyma-cells," Baber). The spaces (areolæ) of this tissue and the lymphatic vessels may be filled with the same colloid substance as that which occupies the vesicles. The blood-vessels and lymphatics are conducted to the vesicles in the interstitial tissue, but the lymphatic vessels do not come into such intimate relations with the walls of the vesicles as the blood-capillary network, the vessels of which are in close contact with the epithelium and may even project between the epithelium-cells.

Occasionally small bodies detached from the main mass of the thyroid are found, having all the structure of the normal thyroid (*accessory thyroids*).

One of the most frequent pathological changes to which the thyroid body is subject consists in the accumulation within its vesicles of colloid substance: in certain forms of goître it distends them to an enormous degree. Removal of the thyroid produces myxœdema.

In the fœtus, and during early infancy, this organ is relatively larger than in after-life; its proportion to the weight of the body in the new-born infant being that of 1 to 240 or 400, whilst at the end of three weeks it becomes only 1 to 1160, and in the adult 1 to 1800 (Krause). In advanced life the thyroid body is liable to become indurated, and frequently contains earthy deposit; its vesicles also attain a very large size.

Vessels and nerves.—The **arteries** of the thyroid body are the *superior* and *inferior thyroids* of each side, to which is sometimes added a fifth vessel, the *thyroidea*

ima. The arteries are remarkable for their large relative size, and for their frequent and large anastomoses; they terminate in a capillary network upon the outside of the vesicles. The **veins,** which are also large, ultimately form plexuses on the surface, from which a *superior, middle,* and *inferior thyroid vein* are formed on each side. The superior and middle thyroid veins open into the internal jugular; the inferior veins issue from a plexus formed in front of the trachea, and open into the innominate veins. The **lymphatics** of the thyroid body form numerous and large anastomosing trunks, both at the surface of the organ and throughout its substance; they originate, according to the observations of Frey, in the connective tissue which unites the gland-vesicles, with the cavity of which they appear not to be in communication. Hürthle has however by using intermittent pressure succeeded in causing injection-material to pass into the vesicles from the lymph-paths. The lymphatics may contain colloid substance, similar to that found within the vesicles (Baber). This appears to pass between the epithelium cells into the interstitial connective tissue and so into the lymphatics.

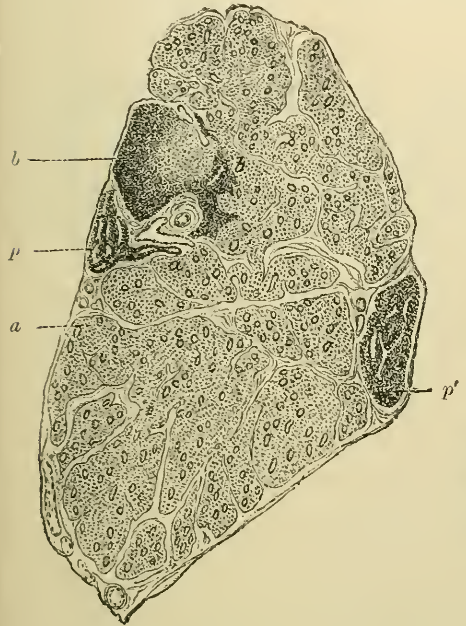
The **nerves** are derived from the *middle* and *inferior cervical ganglia* of the sympathetic. They accompany the blood-vessels. According to Anderson there are no ganglion-cells in their course. Their branches extend close to the base of the epithelium cells.

PARATHYROIDS (GLANDULÆ PARATHYROIDEÆ.)

Under the name of parathyroids Sandström described (in 1880) a pair of small glandular masses, constant in occurrence in man and other mammals, and always lying in close proximity to the lateral lobes of the thyroid body (fig. 325, *p, p'*) They vary in size from 3 mm. to 15 mm. in diameter, being on the average about 6 mm. They are usually flattened, and their colour is reddish-brown, somewhat like that of the thyroid itself. In structure, however, they differ from the thyroid proper, being composed not of hollow vesicles but of solid masses of epithelium-like cells (which sometimes appear in sections as if arranged in anastomosing columns) with numerous convoluted blood-vessels between them (fig 326). Connected with the cell-masses there are frequently lymph-follicles. They differ completely in structure from the normal thyroid and are not therefore to be confounded with the accessory thyroids which have just been mentioned. These bodies have undoubtedly been previously noticed (by Remak, Virchow, and others), but their importance, as shown by their constancy of occurrence, was not recognised nor were they systematically described. Since the appearance of Sandström's account, their structure was independently described by Baber (in 1881), and more recently several observers have directed their attention to these bodies. According to Gley they represent embryonic portions of the true thyroid, and if left after the removal of the latter, they are able to develop further and to take on the functions of the main organ, and it is thus he accounts for the failure to obtain in some animals the usual effects of thyroidectomy. It is however denied by Edmunds that they develop into thyroid tissue proper under these circumstances, although they appear as stated by Gley to undergo hypertrophy if left after removal of the thyroid, and to act to some extent vicariously for it.

Kohn, who has made a careful investigation of the structure of these bodies and their relations to the main part of the thyroid, states that there is one parathyroid ("outer epithelial body") constantly to be met with in mammals on the lateral surface of each lateral lobe of the thyroid and another on the mesial surface of each lateral lobe ("inner epithelial body") (see fig. 325, *p, p'*). Associated in position with these bodies there is, at least in some animals, almost constantly to be met with a small mass of "adenoid" tissue, which has all the structural characteristics of

thymus tissue, including the well-known epithelial nests (concentric corpuscles), and which tends to blend insensibly with the neighbouring interstitial tissue of the thyroid (fig. 325, *b*). According to Prenant, again, the tissue of the parathyroids is similar in general structure and appearance to that of the carotid glands, and is not embryonic thyroid tissue. This author states that it takes origin from the fourth inner branchial cleft of the embryo, from which also part of the thymus and the lateral rudiments



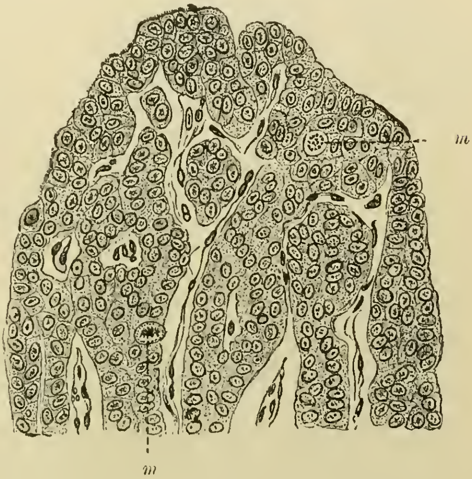


Fig. 325.—Transverse section of the left lobe of the thyroid of a two-months kitten. (Kohn.) $\frac{20}{1}$

a, thyroid tissue ; *b*, *b*, thymus tissue ; *p*, *p′*, inner and outer parathyroid bodies.

Fig. 326.—Part of the outer parathyroid represented in the preceding figure, more highly magnified. (Kohn.) $\frac{500}{1}$

The figure shows the columns of epithelium-like cells with intervening vascular septa of which the parathyroid is composed. *m*, *m*, cells undergoing mitotic division.

of the thyroid are derived (de Meuron, see Vol. I., Part 1, p. 111), whereas the main part of the thymus and the carotid gland are derived from the third cleft.

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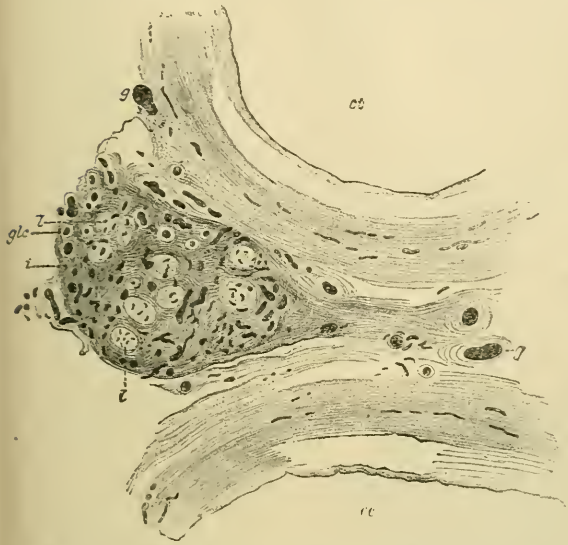
THE CAROTID AND COCCYGEAL GLANDS.

The **carotid glands** (*glandulæ caroticæ*) are small bodies situated just above the bifurcation of the common carotid artery on each side, and between its internal



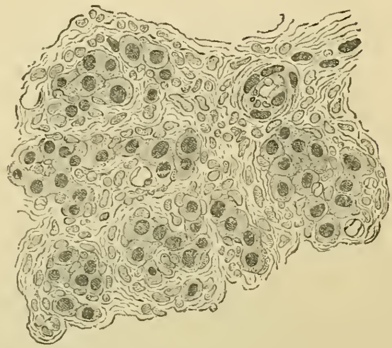


Fig. 327.—Section near the bifurcation of the common carotid artery, passing through the carotid gland. (Marchand.) Somewhat magnified.

ci, *ce*, internal and external carotid arteries cut across ; *gl c*, carotid gland ; *g*, blood-vessels ; *i*, interstitial connective tissue of gland ; *l*, glandular lobules or nodules.

Fig. 328.—Section of part of the carotid gland, human, showing the epithelium-like cells of which the glandular nodules are composed. (Schaper.) Highly magnified.

Numerous blood-vessels are seen in section among the gland-cells.

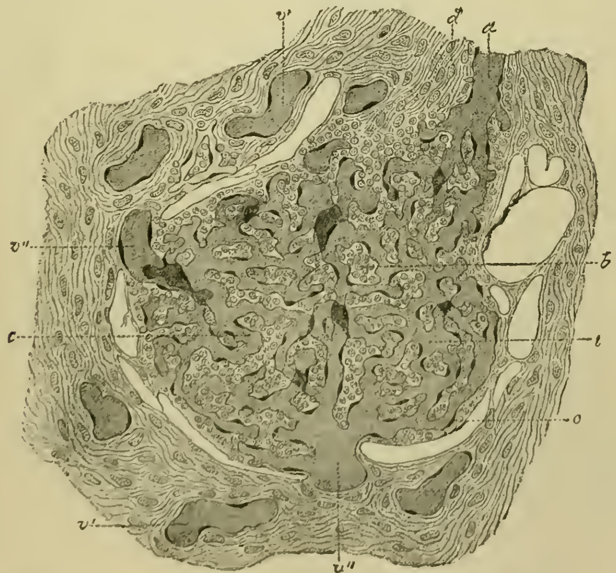


Fig. 329.—Diagrammatic view of the disposition of the blood-vessels in a nodule of the carotid gland. (Schaper.)

a, arteriole entering nodule ; *v''*, veins leaving nodule ; *v'*, veins in connective tissue around nodule ; *t*, enlarged capillary within nodule ; *b*, epithelium-like cells of the gland ; *c*, *c*, boundary of nodule abutting upon lymph-spaces ; *d*, interstitial connective tissue of gland.

and external branches. They are enveloped in connective tissue which also passes into their substance, subdividing them into small nodules. Each nodule is composed of a mass of polyhedral epithelium-like cells, amongst which are distributed numerous wide and tortuously-disposed blood-capillaries, the cells being in close contiguity to the walls of the capillaries. These small organs somewhat resemble in minute structure the parathyroids just described; they are also similar in character to the vascular islets of the pancreas. Their origin is very similar to that of the parathyroid bodies, except that they are developed from the third inner branchial cleft, whereas, as already mentioned, the parathyroids take origin from the fourth cleft. The physiological relations of these bodies are unascertained.

The **coccygeal gland** (*glandula coccygea*, Luschka), is a small organ at most 2·5 mm. in diameter, sometimes broken up into 3 to 6 smaller corpuscles, placed

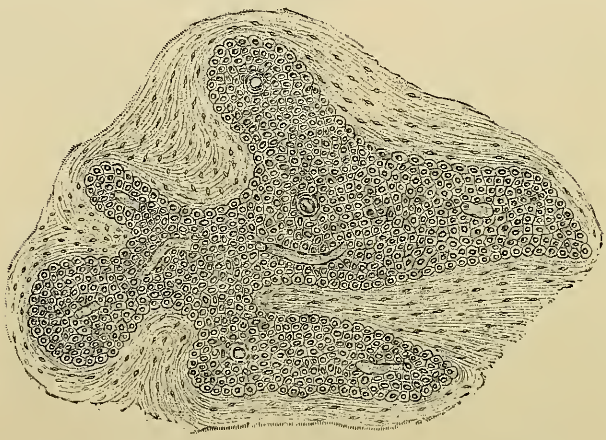


Fig. 330.—Section of an irregular nodule of the coccygeal gland. (Sertoli.) $\frac{85}{1}$

The section shows the fibrous covering of the nodule, the blood-vessels within it and the polyhedral cells of which it is constituted.

immediately in front of the apex of the coccyx and receiving branches of the middle sacral artery. It resembles very closely in minute structure the carotid glands, being composed of masses and columns of polygonal cells, amongst which Eberth has noticed nests of cells similar to the concentric corpuscles of the thymus. The gland-cells closely invest the blood capillaries, which are numerous and tortuous, and here and there show dilatations upon their course. The gland is subdivided into nodular portions by ingrowths of the investing connective tissue which conducts numerous nerves to the glandular part of the organ. Luschka described the gland as rich in ganglion-cells and compared it in this respect with the pituitary body, but this has not been confirmed by later observers. The mode of development and the function of this body are not known.

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THE PERITONEUM.

By J. SYMINGTON.

The abdominal viscera having been described, as well as the disposition of the peritoneum in relation to each of them, it remains to give an account of that membrane in its whole extent, and to trace its continuity over the various parts which it lines or covers.

The peritoneum lines the whole of the anterior abdominal wall, except along a narrow line extending from the umbilicus upwards to the diaphragm, and corresponding to the interval between the two layers of the falciform ligament of the liver.

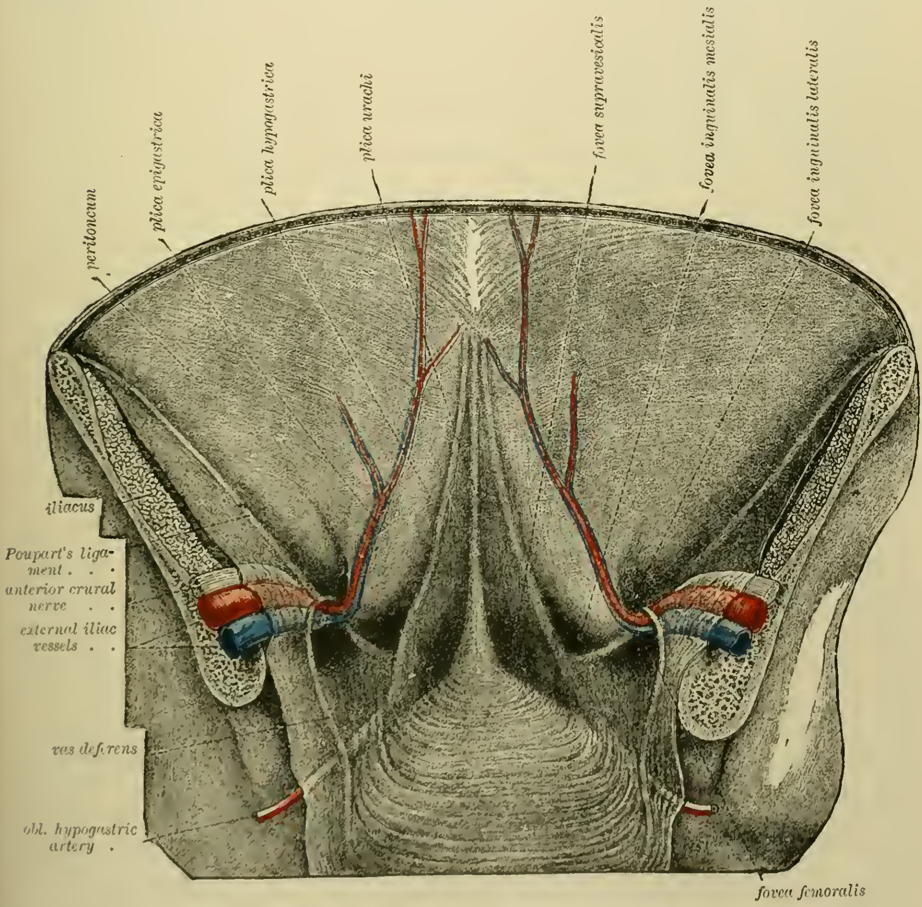
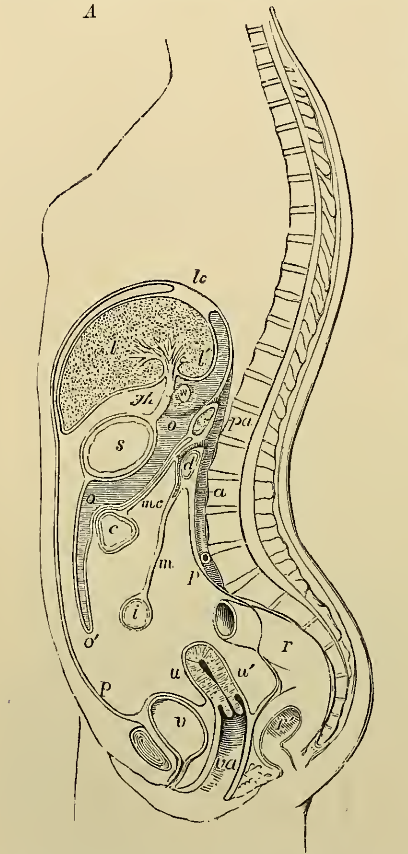


Fig. 331.—View from behind of the lower part of the anterior abdominal wall and of the bladder. (G. D. T., after Joessel.)

This peritoneal fold is usually attached to the abdominal wall slightly to the right of the median plane. For a short distance above the pubis the peritoneum is loosely

connected with the abdominal wall, so that when the bladder becomes distended with urine the serous membrane is detached from the lower part of the abdominal wall. This, however, can only occur to a limited extent, since the peritoneum as it passes upwards towards the umbilicus becomes gradually more firmly adherent to the abdominal wall. In cases of great distension of the bladder an area above the pubic symphysis, two inches in vertical extent, may be uncovered by peritoneum.



Between the anterior wall of the pelvis and the umbilicus the peritoneum is raised into five vertical folds, with intervening depressions, by certain structures which converge towards the umbilicus. These folds are a median one, caused by the urachus, and two lateral, on each side, formed by the obliterated hypogastric artery and the deep epigastric artery (see fig. 331). The depression on the outer side of the deep epigastric artery cor-

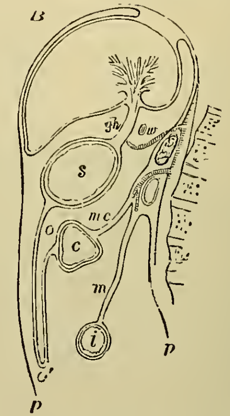


Fig. 332 A.—Diagrammatic outline of a supposed section of the body, showing the inflections of the peritoneum in the female. (Allen Thomson.) $\frac{1}{6}$

The upper part of the section is a little to the right of the median plane in the body, through the quadrate and Spigelian lobes of the liver: below these it is supposed to be median: *l c*, placed above the diaphragm opposite to the coronary ligament of the liver; *l*, liver; *l'*, lobe of Spiegel; *s*, stomach; *c*, transverse colon; *i*, small intestine; *pa*, pancreas; *a*, aorta; *d*, duodenum; *v*, urinary bladder; *u*, uterus; *r*, rectum; *r'*, its lower part opened; *v a*, vagina; *p*, *p*, the parietal peritoneum lining the front and back of the abdominal cavity. The line representing the inflections of the greater sac of the peritoneum will be traced from the neighbourhood of *l c*, where it passes from the diaphragm to the upper surface of the liver, over the upper and lower surfaces of that organ, forming the front of *g h*, the gastro-hepatic omentum, over the front of the stomach down to *o'*, the outer layer of the great omentum; thence passing back to the vicinity of the pancreas, and descending again as the upper layer of the transverse mesocolon. After enclosing the colon it returns as the lower layer of the transverse mesocolon, *m c*, to the root of the mesentery, *m*; it now forms the mesentery and incloses the small intestine, returning to the posterior wall of the abdomen, whence it passes over the rectum, *r*, descends into the recto-vaginal pouch, *u'*, covers the back and front of the uterus and the bladder partially, and regains the anterior abdominal wall above the pubis. In connection with the lesser sac of the peritoneum, *w* marks the position of the foramen of Winslow as if seen beyond the section; the lesser sac, with the cavity of the omentum, is shaded with horizontal lines, and is marked *o o*; round this space the line of the peritoneum may be traced from the diaphragm over the lobe of Spiegel, to the back of the gastro-hepatic omentum, thence behind the stomach and down into the great omentum; it then ascends to the pancreas, which it covers, and thence reaches again the diaphragm.

Fig. 332 B is a sketch of part of a section similar to that of A, but showing a condition more commonly found in the adult, according to which the two layers of the mesocolon are continuous with the posterior pair of the layers of the great omentum.

responds to the internal abdominal ring, that internal to the artery to Hesselbach's triangle, while the one below Poupart's ligament is opposite the femoral ring. The significance of these pouches will be found described in connection with the anatomy of the groin (see separate Appendix).

After lining the anterior wall of the abdomen, the peritoneum passes round on each side to the lumbar and iliac regions, where it meets with the right and left portions of the large intestine. On the right side it completely invests the cæcum and its vermiform appendix, and it also provides the latter with a mesentery. Higher up it covers the ascending colon in front and on the outer side, the remaining part of the circumference of the bowel being usually uncovered.

Leaving the right colon, the peritoneum gives a scanty covering to the lower part of the anterior face of the right kidney and adjoining third portion of the duodenum where that intestine comes down from behind the transverse mesocolon; lower down it continues over muscles and vessels to the root of the mesentery, proceeds forwards to form the right layer of that fold, passes round the jejunum and ileum, affording them their peritoneal coat, and returns back to the vertebræ, thus completing the mesentery on the left side. The membrane now passes in front of the lower portion of the left kidney to the left colon, which it invests much in the same manner as the right, and is then continued over the lateral wall on the left side to the front again, thus completing a horizontal circuit round the abdomen. Although the descending colon is usually uncovered behind and on its inner side, yet occasionally it is entirely invested by peritoneum and provided with a mesocolon. The frequency, however, with which a descending mesocolon occurs has been much exaggerated.

Where the colon forms its sigmoid loop it is completely invested by peritoneum, which attaches it by a comparatively free and moveable sigmoid mesocolon to the fascia of the left iliac fossa.

From this part, and from the lower end of the mesentery the peritoneum is continued into the pelvis. It there invests the upper part of the rectum completely, forming a mesorectum behind. Lower down the membrane gradually quits the intestine, first behind, then at the sides, and finally in front, whence it is reflected on the base and upper part of the bladder in the male, and forms here the *recto-vesical pouch*, the mouth of which is bounded by a crescentic fold on each side, named *plica semilunaris*. From the apex of the bladder the peritoneum passes on to the urachus as already described. In the female the peritoneum passes from the rectum to the upper part of the vagina, and over the posterior surface, the fundus, and upper part of the anterior surface of the uterus, whence it goes to the bladder. The *recto-vaginal pouch* (pouch of Douglas), like the recto-vesical, is bounded above by its semilunar folds, and the uterine peritoneum forms at the sides the broad ligaments of the uterus, along the upper border of which the Fallopian tubes receive from it a serous covering; at their fimbriated openings the peritoneum is continuous with the mucous membrane lining the tubes.

The peritoneum, on being traced to the upper part of the abdomen, is found to line the vault of the diaphragm, adhering moderately to the muscular and firmly to the tendinous part, and continuing down behind as far as the hinder surface of the liver and the œsophageal opening. It then passes forwards on to the liver, forming the falciform, coronary, and lateral ligaments of that organ, already specially described.

Turning round the anterior border it passes back on the under surface; but, after covering the quadrate lobe, and arriving at the transverse fissure, it meets with a peritoneal layer from behind, and in association with it, stretches from the liver to the stomach, to form the lesser omentum, as will be presently explained. To the right of this part it invests the gall-bladder more or less completely, and the under

surface of the right lobe of the liver, covers anteriorly the adjacent part of the duodenum, and passes to the upper end of the right kidney, forming here a slight fold, named *hepato-renal ligament.* It then invests the hepatic flexure of the colon and reaches the right colon, on which it has been already traced. To the left of the longitudinal fissure the peritoneum invests the whole of the left lobe of the liver, and stretches out as the long left lateral ligament above and beyond the œsophageal opening. It then passes down over that opening and covers the front and left side

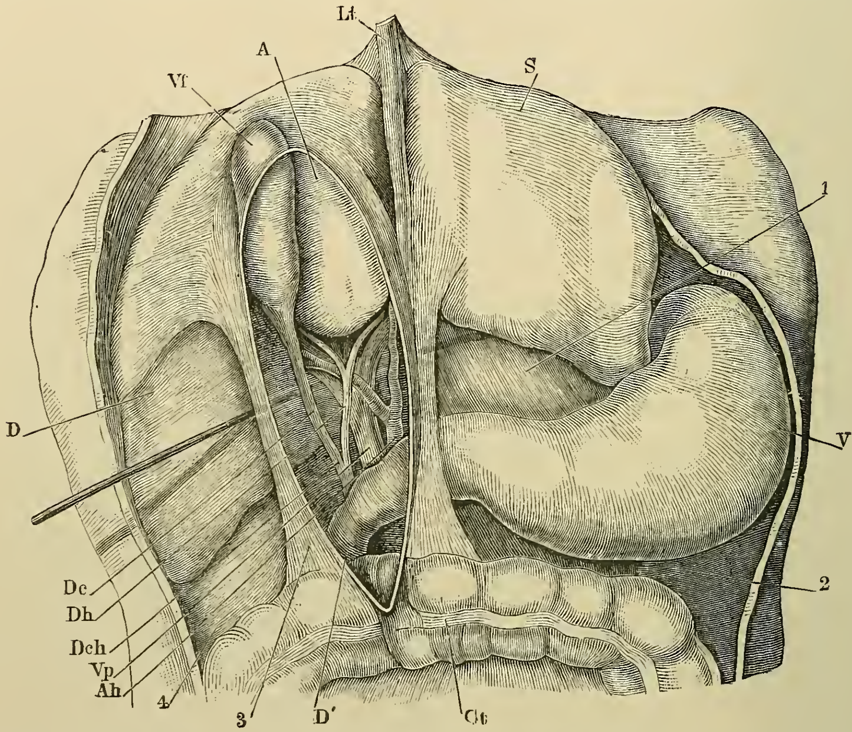


Fig. 333.—Front view of the viscera of the upper part of the abdomen in a child. (Henle.)

The liver is drawn upwards in order to show its under surface and the small omentum, together with the entrance of the foramen of Winslow, into which a probe is passed.

A, quadrate lobe of liver; S, left lobe; D, right lobe; Lt, ligamentum teres with its peritoneal covering forming the falciform ligament; V, stomach; Ct, transverse colon; D′, duodenum; 1, small omentum; 2, part of great omentum; 3, right part of small omentum, its anterior layer being divided to show its contents, viz., Ah, hepatic artery; Vp, portal vein; Dch, common bile-duct; Dh, hepatic duct; and Dc, cystic duct; 4, peritoneum reflected from the liver over the upper part of the right kidney, or hepato-renal ligament.

of the gullet, spreads over the left end of the stomach, where it passes off to invest the spleen, forming a duplicature named the *gastro-splenic ligament,* or *gastro-splenic omentum*, for it is connected below with the great omentum, and often reckoned as a part of it. When the membrane passes from the diaphragm to the stomach it forms a small duplicature to the left of the œsophagus, named the *gastro-phrenic ligament;* it extends also as a generally stout and well-marked fold (the *costo-* or *phreno-colic ligament*) from the diaphragm opposite the tenth and eleventh ribs to the splenic flexure of the colon, then passes over the splenic flexure, and reaches the left kidney and descending colon, where it has been already described.

Omenta.—The arrangement of the remaining part of the peritoneum—that

between the stomach, liver, and transverse colon—is somewhat complex, in consequence of the membrane forming in this situation a second and smaller sac, which communicates towards the right with the general cavity by a narrow throat, named the *foramen of Winslow.* This passage, which readily admits two fingers, is situated behind the bundle of hepatic vessels which stretches between the liver and duodenum; behind the orifice is the inferior vena cava ; above is the caudate lobe of the liver ; and its lower boundary is formed by the duodenum and a curve of the hepatic artery. From this opening the lesser sac spreads out to the left behind the general or main sac of the peritoneum. It covers a part of the posterior abdominal wall, but in front and below it is applied to the back of the main sac, to which it adheres except where the stomach is interposed. Moreover, it indents, as it were, the back of the main sac, and between the stomach and colon protrudes into it in the form of a great pouch—the bag of the omentum,—which thus has a double coat, formed by the apposition of the membranes of both sacs. To trace this arrangement more particularly : suppose a finger pushed into the foramen of Winslow, and the thumb brought to meet it from before, to the left of the hepatic vessels ; the membrane held between is double ; its anterior layer (from the greater sac) turns round the hepatic vessels into the foramen, and then belongs to the lesser sac. The double membrane, so constituted, is the *small* or *gastro-hepatic omentum.* From the point indicated it may be followed to the transverse fissure of the liver, where its laminæ separate, the anterior, which has already been traced from above, spreading on the adjacent part of the liver, the posterior covering the Spigelian lobe, where it will be again met with. The attachment of the combined layers continues backwards from the left end of the transverse fissure along the fissure of the ductus venosus to the diaphragm on which it runs a short way to reach the œsophagus, where the anterior lamina covers the end of that tube in front and on the left, and the posterior lamina invests it on the right and behind. From this point, as far as the pylorus, the small omentum is attached to the lesser curvature of the stomach, where its laminæ separate—one covering the anterior and the other the posterior surface of the organ—but meeting again at the great curvature, they pass down in conjunction to a variable distance before the small intestine to form the anterior part of the great omental sac, and then turn up to form its posterior wall. Meeting next with the transverse colon, the two laminæ separate, and enclose that intestine, but meet again behind it to form the transverse mesocolon. This extends back to the anterior border of the pancreas, from which its inferior layer passes backwards over the inferior surface of this organ and then turns downwards over the posterior wall of the abdomen, and forms the mesentery, where it has been already recognized. The superior layer, on the other hand, which, as will be understood, belongs to the lesser sac, covers the front of the pancreas, the cœliac artery and its main divisions, the upper part of the left kidney, and the portion of the diaphragm between the aortic and caval orifices, and may extend to the left end of the pancreas and gastric surface of the spleen, partially investing the latter organ and forming part of the gastro-splenic omentum. It then goes forward on the Spigelian lobe to the transverse fissure, and the line of attachment of the lesser omentum of which it then becomes the posterior layer. More to the right the layer in question passes over the vena cava, and continues into the general peritoneum beyond the foramen of Winslow. The gastric and hepatic arteries, especially the former (Huschke), may raise the membrane into folds which project into the cavity.

From the description given it will be understood that, as the sides or walls of the great omental bag consist of two peritoneal layers, its whole thickness (in its usually empty and collapsed state) will comprehend four layers. But although the bag may be inflated in its whole extent in the infantile body, its sides afterwards cohere, and it becomes impervious in its lower part. Fat, moreover, accumulates

between its laminæ; long slender branches also pass down into it from the gastro-epiploic vessels.

The part of the membrane just described, which is attached to the great curvature of the stomach and transverse colon, and which is connected also with the gastro-splenic ligament (or omentum), is usually named the *great* or *gastro-colic omentum.* This may reach the hepatic flexure and pass a certain way down on the right colon, and this part has been distinguished by Haller and others as the *omentum colicum.* The great omentum (proper) usually reaches lower down at its left border, and it is said that omentum inguinal herniæ are more common on the left side.

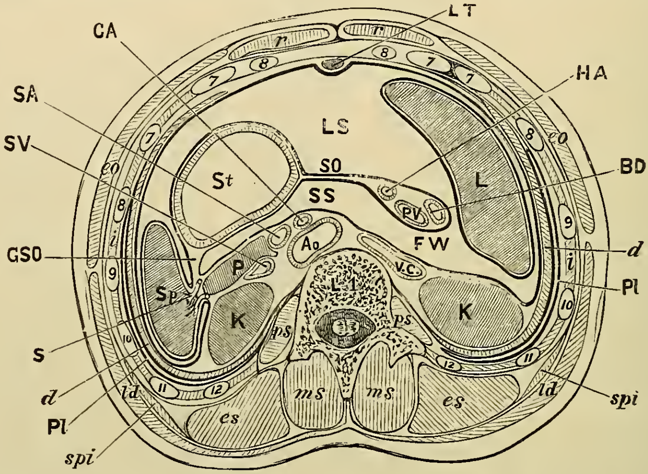


Fig. 334.—Diagram of a horizontal section through the abdomen at the level of the foramen of Winslow. (R. J. Godlee.)

L1, first lumbar vertebra; 12, 11, 10, &c., successive ribs; *r*, rectus muscle; *eo*, external oblique; *ld*, latissimus dorsi; *spi*, serratus posticus inferior; *i*, intercostal muscles; *es*, erector spinæ; *ms*, multifidus spinæ; *ps*, psoas; *d*, diaphragm.

Ao, aorta; V.C, inferior vena cava; C A, coronary artery; S A, splenic artery; S V, splenic vein; S, splenic vessels cut as they enter the spleen; H A, hepatic artery; P V, portal vein; B D, common bile duct.

L, liver; L T, ligamentum teres or round ligament of the liver; St, stomach; Sp, spleen; P, pancreas; K, kidney; L S, large sac of peritoneum; S S, small sac; S O, small omentum; G S O, gastro-splenic omentum; F W, foramen of Winslow; Pl, pleura.

The peritoneum is represented by a thick dark line. It can be traced from the middle line anteriorly, where it is seen investing the round ligament of the liver and forming the commencement of the falciform ligament, along the right side of the abdominal wall, over the front of the right kidney, to the inferior vena cava where it forms the posterior boundary of the foramen of Winslow; from the latter spot the small bag extends over the pancreas and left kidney nearly as far as the spleen, and then is reflected backwards along the back of the small omentum to the front of the foramen; here becoming large bag again, it turns round the hepatic vessels, forms the anterior layer of the small omentum, covers the front of the stomach, forms the gastro-splenic ligament or omentum as it is reflected on to the spleen, which it invests almost completely, and is thence continued along the diaphragm and abdominal wall back to the middle line.

The description now given of the relation of the omentum to the mesocolon agrees with the appearances most frequently seen in the adult subject, the exterior (here also posterior) layer of the great omentum being described as separating from the layer within, belonging to the omental sac, when it reaches the transverse colon so as to pass behind or below that viscus, and as proceeding thence backwards to the abdominal wall as the posterior or lower layer of the transverse mesocolon. In the young fœtus, however, two layers of peritoneum pass from the greater curvature of the stomach upwards and backwards to the posterior abdominal wall forming the mesogastrium, and the transverse colon possesses an independent mesocolon. Sub-

sequently the posterior layer of the mesogastrium fuses with the anterior layer of the transverse mesocolon (see Development, Vol. I., Pt. I., p. 107). Occasionally in the child, and even in the adult, these layers remain distinct.

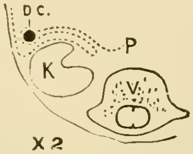


Fig. 335.—Transverse section through the abdomen of a fœtus $3\frac{1}{4}$ inches long. (J. S.)
V, body of lumbar vertebra; K, left kidney; D.C., descending colon; P, peritoneum.

Various peritoneal fossæ or pouches are often found on the posterior wall of the abdomen. They are of importance surgically on account of the fact that portions

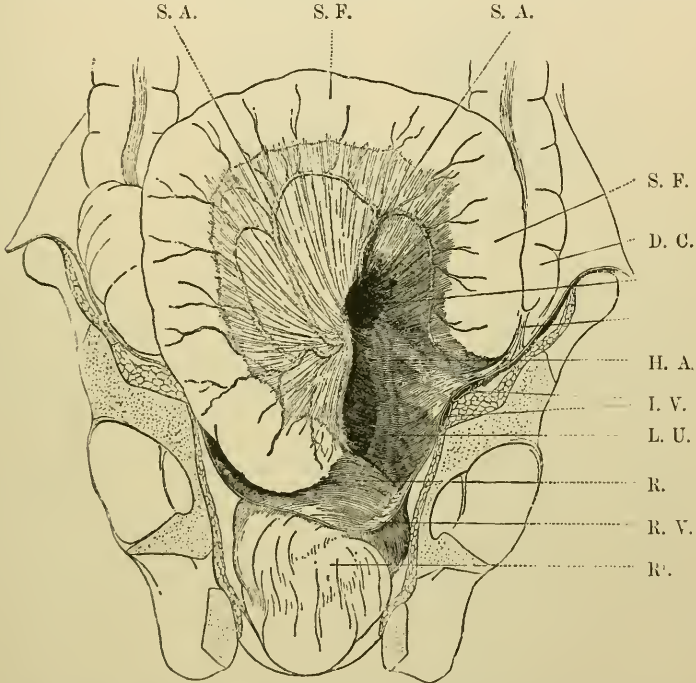


Fig. 336.—View of inter-sigmoid fossa. The pelvis has been divided in a coronal plane opposite the bottom of the recto-vesical pouch, and the sigmoid loop has been turned upwards and to the right. (Jennesco.)

D. C., descending colon; S. F., sigmoid colon; R., rectum covered by peritoneum: R[1], rectum uncovered by peritoneum: R. V., recto-vesical fold of the peritoneum; S. A., branches of the sigmoid artery; L. U., left ureter; I. V., external iliac artery and vein; H. A., obliterated hypogastric artery.

of the intestine are liable to become lodged in them, giving rise to retro-peritoneal herniæ.

Several of these fossæ are found in relation with the cæcum and have already been described (see p. 111). Another fossa, the *inter-sigmoid*, is very commonly met with during the fifth and sixth months of fœtal life. This recess is funnel-shaped and opens below, behind the root of the mesentery of the sigmoid colon. It extends upward for a variable distance along the course of the ureter. In the young fœtus (see fig. 335) the descending colon is connected by a relatively long mesentery to the

posterior abdominal wall near the median plane. The posterior layer of the descending mesocolon soon unites with the peritoneum in front of the kidney, but internal to this organ the fusion of the two layers of peritoneum does not occur so readily, hence the formation of a tubular recess, which communicates below with the general peritoneal cavity. This fossa is only occasionally met with, in a well developed condition, in the adult. Several fossæ, *duodenal* and *duodeno-jejunal*, are

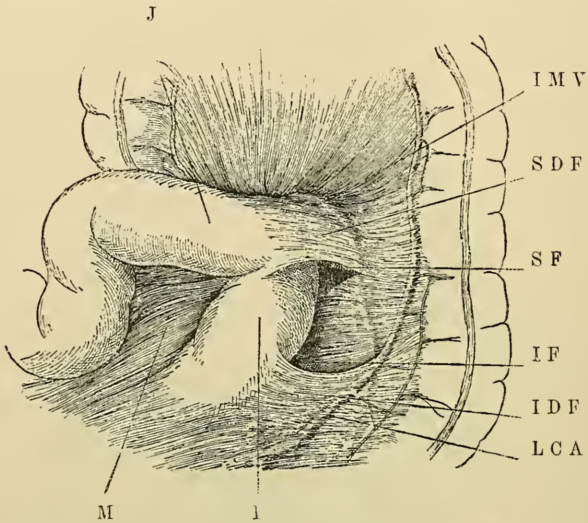


Fig. 337.—Superior and inferior duodenal fossæ. The transverse colon and the great omentum have been turned upwards and the convolutions of the jejuno-ileum to the right side. (Jonnesco.)

J, upper end of jejunum ; M, the mesentery ; D, terminal or 4th part of duodenum ; S D F, superior duodenal fold of peritoneum ; S F, superior duodenal fossa ; I D F, inferior duodenal fold ; I F, inferior duodenal fossa ; I M V, inferior mesenteric vein ; L C A, left colic artery.

sometimes present near the termination of the duodenum. According to Jonnesco there are five varieties of fossæ met with in this region ; viz., *inferior duodenal*, *superior duodenal*, *retro-duodenal*, *para-duodenal*, and *duodeno-jejunal*. The most frequent of these fossæ, *inferior duodenal*, lies on the outer side of the terminal part of the duodenum and has its orifice above. It is bounded anteriorly by a thin fold of peritoneum, which is attached to the posterior abdominal wall along a vertical line to the left of the duodenum, while on the right side it is attached to the duodenum. This fold possesses an upper, free and somewhat crescentic margin. In other cases the fossa, *superior duodenal*, has its orifice directed downwards, or these two fossæ may both occur in the same subject (see fig. 337).

For the recent literature of the Peritoneum, see pp. 69, 70.

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